METAL PROGRESS

FEBRUARY 1949

NOW MAKING PRODUCTION HISTORY

PERFORMANCE DATA		
	* 6 MIN. HEATING CYCLE	4 MIN. HEATING CYCLE
Discharge Rate	10.7 sec. ea.	8.2 sec. ea.
Pieces per hour	336	440
Weight	1545 lbs. per hour	2000 lbs. per hour

*Operation held to 6 min. heating cycle because of trim press rate of operation. Furnace is designed for 4 min. heating cycle.

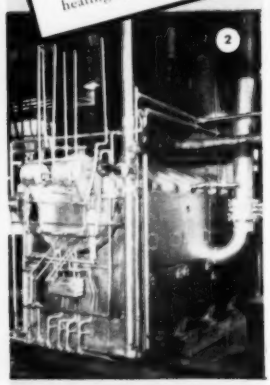
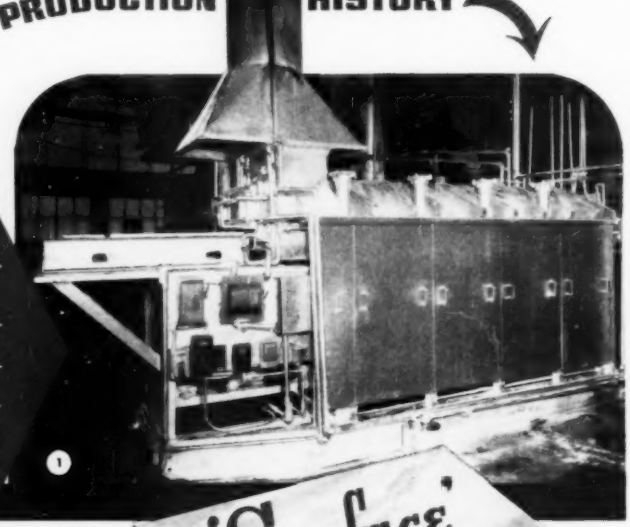


Figure 1. *Sideview of 'Surface' Rapid Billet Heater showing top of furnace heater tube, enclosed lower sections containing piping, controls, and pusher type charging mechanism.*

Figure 2. *View of the discharge end which illustrates the cylindrical shape of the unit. Note downward sloping water-cooled skid rails.*



'Surface'

RAPID BILLET HEATING WITH GAS EXCELS OVER OTHER METHODS

Unusual methods and equipment design features have been used in the newly developed 'Surface' gas-fired Rapid Billet Heating Furnace installed in the plant of Willys-Overland Commercial Forge Plant, Toledo, Ohio. Outstanding are:

- Rapid firing-up time and method to obtain high temperatures
- Method to transfer heat rapidly to the billets
- Control of the heating cycle to prevent overheating
- Method for minimizing oxidation and die wear
- Method of work handling. Accommodation of various sizes and shapes of billets. Minimum or no lost time for change-over
- Low initial cost of equipment . . . small floor space required

REDUCED DIE COST—POLISHING TIME: The die cost per tractor link forging is 5c. This is about one-third that of a conventional oil or gas-fired furnace and about the same as induction heating methods. The rapid heating process produces a softer scale and reduces the amount of die polishing time.

EQUIPMENT COST LOW: The initial or equipment cost of complete furnaces of this type ranges between $8.00 and $18.00 per pound per hour of productive capacity. This compares with from two to four times this range for any other heating method, if all necessary equipment is included. With the four minute heating rate the operating costs should be further lowered.

Write for complete story on "Rapid Billet Heating with Gas."

SURFACE COMBUSTION CORPORATION • TOLEDO 1, OHIO

'Surface' INDUSTRIAL FURNACES

PRODUCTION TRIPLED!
UNIT COST CUT 60%

Nash oil pan showing TOCCO-brazed drain flange. Photo courtesy Nash Motors.

with TOCCO* Induction Heating

Even if your products are entirely different in size and shape TOCCO can probably provide similar cost reductions and production increases for you.

● *Nash Motors,* Kenosha, Wisconsin reports the following benefits from TOCCO Induction brazing of drain flanges to automobile oil pans:

1. **PRODUCTION TRIPLED**— Using a hand torch, production was only 21 brazed assemblies per hour. TOCCO brazes 75 per hour—357% of former output!

2. **COSTS CUT**—At the same time TOCCO Induction brazing cuts labor and material costs from $12.75 to $4.90 per hundred—a reduction of 60%, representing a saving of $6.00 every hour.

3. **OTHER ADVANTAGES**—include a neater, better looking brazed joint, and a complete elimination of leakers and subsequent repair costs.

TOCCO Engineers are glad to help you find applications in your plant where TOCCO Induction Heating would increase your production, cut your costs and improve your products.

THE OHIO CRANKSHAFT COMPANY

TOCCO

Mail Coupon Today

FREE BULLETIN

THE OHIO CRANKSHAFT CO.
Dept. R-2, Cleveland 1, Ohio

Please send free copy of 60 page book —"Induction Heating"

Name _____

Position _____

Company _____

Address _____

City _____ Zone _____ State _____

LATROBE
DESEGATIZED

High Speed Steels and
High-Carbon, High-Chrome
Die Steels

means extra toughness

There is no "mystery" to the extra toughness of DESEGATIZED* Brand Steels . . . FULL STRUCTURAL UNIFORMITY is the reason for this important added quality . . . FULL STRUCTURAL UNIFORMITY is available in Latrobe DESEGATIZED Brand Steels because these steels are the only tool steels produced today consistently free from harmful carbide segregation, a property which robs uniformity from average tool steels.

These uniform material properties assure users of:

* EXTRA TOUGHNESS * EASE OF FABRICATION * CONSISTENT HEAT TREATING PROPERTIES and REDUCED HEAT TREAT HAZARD * EVEN WEAR RESISTANCE * LONGER TOOL LIFE . . . .

LESCO

Write or call your nearest Latrobe representative. Sales engineers stand ready to give you the important facts on Latrobe Desegatized Brand Steels.

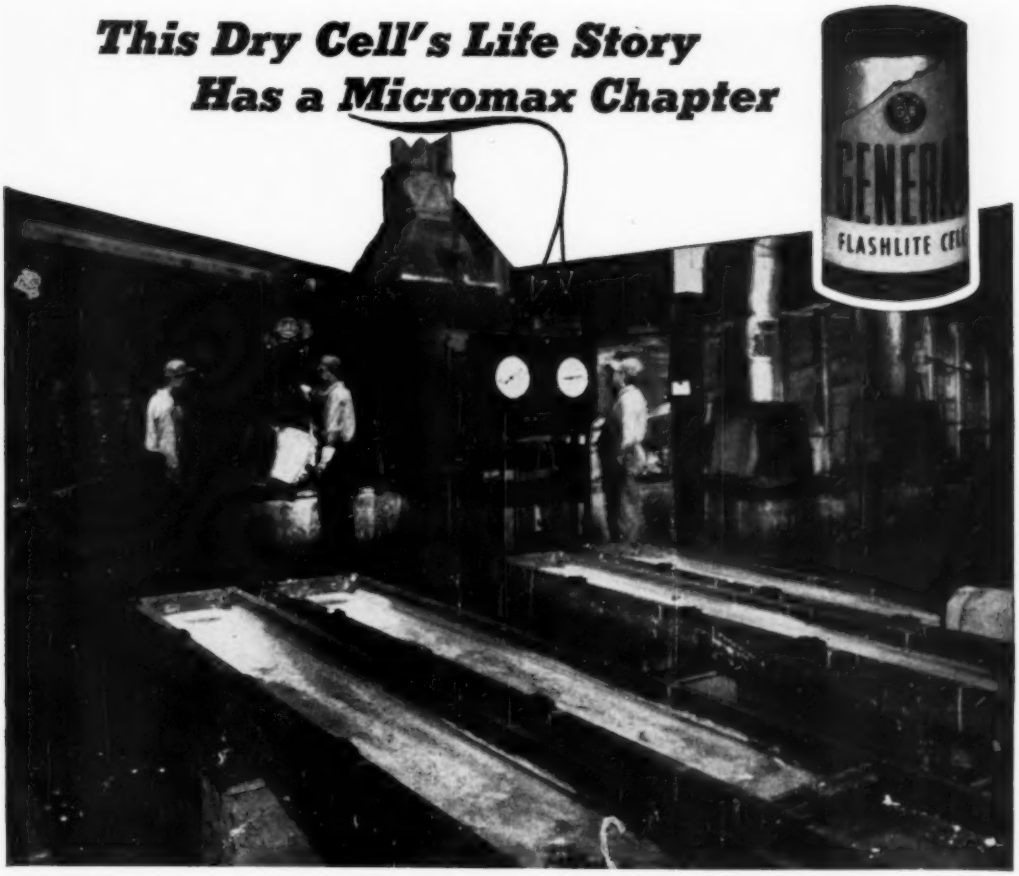
LATROBE ELECTRIC STEEL COMPANY

DESEGATIZED BRAND STEELS

LATROBE, PENNA.

*Trade Mark Registered U. S. Pat. Office.

This Dry Cell's Life Story Has a Micromax Chapter



Zinc "cans" for dry cells take form by hundreds of thousands at the Dubuque, Iowa, plant of General Dry Batteries, Inc. And, because the zinc goes through a melting stage, in the 300,000-lb furnace shown above, correct temperature of the melt is quite important. For the molten zinc is cast, rolled, punched into buttons and extruded to the final cell shape, and proper temperature in the furnace can reach right down the line and help many operations which follow.

Measuring Temperature of a Zinc "Lake"

To be sure of fully-dependable temperature facts, General Dry Batteries chose the two Round-Chart Micromax instruments shown above. Measuring furnace temperatures, these instruments are glanced at every few minutes by the melters. The slightest shift in temperature brings prompt action, for the 150-ton "lake" of zinc holds so much heat that it simply cannot be permitted to start swinging or cycling. By reporting all temperature changes accurately and dependably, Micromax enables the "General" melters to hold the great mass constantly in the narrow band which spells maximum production of quality cell-zinc.

Micromax Pyrometers are supplied in strip-chart as well as round-chart models and for any desired form of automatic control. For further information, write to Leeds & Northrup Co., 4927 Stenton Ave., Phila. 44, Pa.

MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

LEEDS & NORTHRUP CO.

Jrl. Ad N-33-665(1)

Metal Progress is published and copyrighted, 1949, by American Society for Metals, 7301 Euclid Avenue, Cleveland, Ohio. Issued monthly; subscriptions $7.50 a year. Entered as second-class matter Feb. 7, 1921, at the post office at Cleveland, Ohio, under the act of March 3, 1879.

...Thanks to

an Engineering Department that THRIVES ON THE "IMPOSSIBLE"

The picture of a casting can tell you nothing about its actual value. But a close-up view of the organization behind it . . . the plant, the people who work there, the facilities they employ, the sum total of their intelligence and experience . . . give practically all the information necessary to determine whether or not you may expect *top quality* in that casting.

Everyone here is justifiably proud of the Alloy Casting Company . . . and does everything possible to maintain its high ideals, standards of craftsmanship, business ethics, and technical progress. The engineering department is typical. That's why *"Call Your Nearest Accoloy Engineer"* is always the advice of so many industrial men who demand *top quality* in alloy castings.

ALLOY CASTING COMPANY
Champaign, Illinois

ENGINEERING OFFICES IN PRINCIPAL CITIES

Chicago: F. J. Staral—Tel: Delaware 4430 Detroit: Frank W. Faery—Tel. Temple 1-7878

TIMKEN® tube engineering service guarantees clean-up with

MINIMUM MACHINING TIME AND SCRAP LOSS

SELECTING the right size seamless tube to make hollow cylindrical parts is not as simple as you might think.

Sometimes you may find you have tubing on hand which requires too much machining—wastes material and time. And sometimes you don't have *enough* metal to fill out your dimensions.

How to be sure of getting the *right* size tube? Consult with Timken. Timken tube engineering service will analyze the specifications for your finished part and recommend the most economical size Timken tubing for the job. Chances are it will be a lighter weight tube than you're using now . . . with a sizeable saving in material cost.

You get the saving—we take the risk

We take all the risk! We *guarantee* that the Timken tube we give you will clean up to your finished dimensions!

Timken tube engineering service can save you material and machining time, and give you guaranteed clean-up for three main reasons:

First, one of our engineering departments devotes its full time to the calculation of the most economical tube size for your particular requirements. These men have had years of contact with mechanical tubing problems in practically every large scale manufacturing industry.

Second, every step in the manufacture of Timken tubing is rigidly controlled in our own mills, resulting in outstanding uniformity of dimensions. This greater uniformity permits a minimum stock removal in the Timken tubing you use.

Third, Timken has the largest assortment of roll sizes of any mechanical tubing mill in the country. This means you have the largest selection of hot-rolled tube sizes to choose from.

90% of Timken tubing bought this way

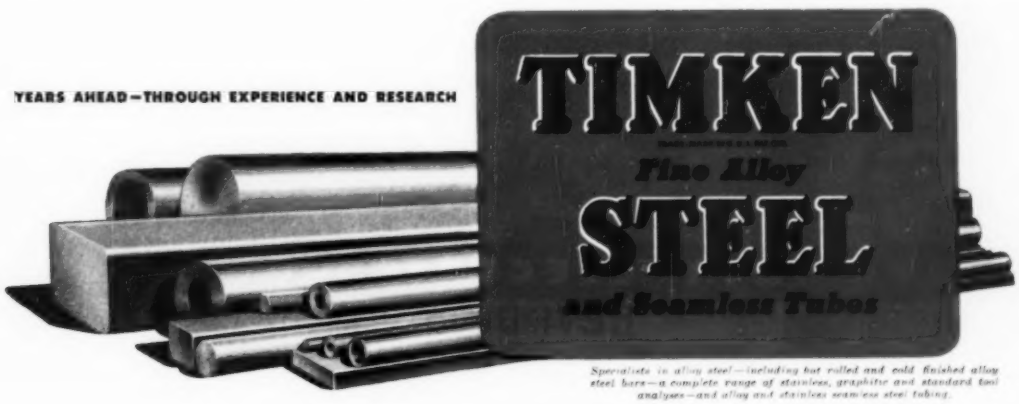
So fully proved and widely recognized are the advantages of Timken tube engineering service that today 90% of Timken mechanical tubing is bought on that basis.

Let Timken tube engineering service make an analysis of your requirements and recommend the most economical size tube for your job, guaranteed to clean up. No cost or obligation. Simply provide the data indicated below to The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable address: "TIMROSCO".

All you have to do is give us this information:

1. **FINISHED PART DIMENSIONS.** Maximum OD x Minimum ID x Length. Blue print or sketch preferred. Dimensions should include applicable tolerances and should be identified as "finish machined" or "finish ground".
2. **MACHINING POSITION.** Complete sequence of operations when practical.
3. **CONDITION DESIRED.** Hot rolled, cold drawn, rough turned, or rotorolled.
4. **GRADE AND QUALITY OF STEEL.**

YEARS AHEAD—THROUGH EXPERIENCE AND RESEARCH



Specialists in alloy steel—including hot rolled and cold finished alloy steel bars—a complete range of stainless, graphitic and standard tool analyses—and alloy and stainless seamless steel tubing.

Jeffrey Manufacturing Co., Columbus, Ohio, reports . . . "this furnace is in constant use and has produced results considerably superior to those previously obtained."

"considerably superior"

HEVI DUTY *Multi Range* CONVECTION FURNACES

give you a wide range of temperatures with a high degree of uniformity . . .

Here is an all-purpose furnace that gives you temperature uniformity in the 400° to 1850° F. range. The Jeffrey Manufacturing Co. is using this model for hardening and drawing operations on large parts and shafting and occasionally for pack carburizing and find it "considerably superior" for their type of operation. Bulletin HD 341 gives you all the details, types, sizes and specifications as well as special features. Write for your copy today!

HEVI DUTY ELECTRIC COMPANY

HEAT TREATING FURNACES **HEVI DUTY** ELECTRIC EXCLUSIVELY

DRY TYPE TRANSFORMERS — CONSTANT CURRENT REGULATORS

MILWAUKEE 1, WISCONSIN

Research Leadership back of every Ingot

Quality Ingot is your assurance of Quality Castings

Apex intense search—and research—for improved alloys give you the quality Alloys That Are Best By Test—from Ingot to Casting.

Apex Smelting Company
Chicago • Cleveland

2537 WEST TAYLOR STREET, CHICAGO 12, ILLINOIS
6700 GRANT AVENUE, CLEVELAND 5, OHIO

They saved $14,500 by specifying Armco "ELC" Stainless!

When this manufacturer found he could save $14,500 on 10 new processing tanks by specifying ARMCO "ELC" Stainless Steel, it didn't take him long to switch from a non-ferrous metal formerly used.

Besides saving money, his new equipment has excellent resistance to heat and corrosion, high strength, and comparatively light weight.

His old tanks were subjected to pressures of 40 psi. The new tanks were to carry 75 psi at 300° F. So he asked a fabricator for engineering designs and price quotations on 10 tanks made of two different metals. This is what he learned:

Metal "A" Tanks—Cost: $51,000. Because of pressures and temperatures 3/4" and 9/16" plates would be required.

ARMCO Type 304 "ELC" Tanks—Cost: $36,500. Because of the high strength of this metal only 1/4" plates were needed throughout.

The fabricator submitted another quotation—on a type of Stainless Steel commonly used in tanks of this kind. It was several thousand dollars higher than for ARMCO "ELC."

LOW IN CARBON

These savings are possible with Armco's new "ELC" because of its low carbon content (.03% maximum), which eliminates intergranular corrosion. Both Type 304 ELC and Type 316 ELC *cost less* than Stainless Steel grades commonly used in welded equipment exposed to corrosive conditions at service temperatures below 800° F. No annealing is necessary, except where engineering requirements specify stress-relief.

If this manufacturer's experience suggests ways for you to cut equipment-costs, write us for full information. ARMCO Engineers will be glad to work with you. Just address Armco Steel Corporation, 83 Curtis Street, Middletown, Ohio.

Are YOU PAYING for Stainless but not using it?

Labor costs are such a large part of the final cost of your products or equipment that ARMCO Stainless Steel is more than ever your "best buy" for today's dollar. This is why:

1. In production equipment, long-range costs of ARMCO Stainless are lower than for short-lived materials because of fewer costly replacement installations, much less maintenance expense.
2. Operating costs are lower too because Stainless equipment is easy to keep clean and efficient. There is less "down-time."
3. First cost in consumer products is actually lower in many cases, because no plating is needed to protect this solid rustless metal.
4. Sales appeal is tops. Buyers prefer Stainless for its lasting beauty, its trouble-free service.

ARMCO

ARMCO

STAINLESS STEELS

HERE'S HOW...

LINDBERG
INDUCTION HEATING

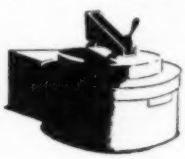
increases hardening production 77% . . . reduces heating cost 55%

Woodstock Typewriter Company, manufacturers of the nationally popular Woodstock Typewriter, use this Lindberg 3 KW Electronic Induction Heating Unit to harden ends of sub levers. Levers are placed on a "dial fixture" as shown—pass through inductor block—and are automatically ejected into water quench. Hardness is required to a point 11/16" from end of lever—but no farther! This is important as levers are later formed, and breakage would result if hardness extended into formed area. With Lindberg Induction Heating, hardened area limit is easily held to .040". Former method which employed belt that conveyed parts under a series of flames resulted in variations of as much as 1/8".

Check this "Before and After" story of increased production, reduced fuel cost and precisely controlled limit of hardened area.

	BEFORE	AFTER
Levers hardened per hour	900	1600
Heating cost per 1000 levers	25¢	11¢
Limit of area of hardness controlled to within—	.5"	.040"

Write for Bulletin 1410 "Lindberg Electronic Induction Heating." Electronics Division, Lindberg Engineering Company, 2448 W. Hubbard Street, Chicago 12, Illinois.

LINDBERG  FURNACES

The Complete ElectroniK Story

POTENTIOMETER

New Catalog 15-13

...Yours For The Asking!

There's a Brown ElectroniK Potentiometer with electric contact or proportional control for *every* temperature process. Every style . . . strip chart, circular scale, circular chart . . . is fully explained and described in new Catalog 15-13. Typical control systems, explanatory tables, and style selection data are included to help you choose the right instrumentation. Send for your copy today and you'll have *the complete story on the complete Brown ElectroniK line.*

MINNEAPOLIS-HONEYWELL REGULATOR CO.
BROWN INSTRUMENTS DIVISION
4503 Wayne Ave., Philadelphia 44, Pa.
Offices in principal cities of the United States, Canada and throughout the world

BROWN *Advanced Instrumentation* FOR METAL WORKING

Product of MINNEAPOLIS Honeywell

The gains made by this company* in soldering kitchen utensil assemblies are profitable from any angle.

They saved $6,384 every 28 working days. They slashed power costs heavily. They cut rejects. They reduced polishing time sharply. And they stepped up production from one utensil per man-hour to 600 per man-hour!

The skillful application of work-handling equipment and Westinghouse radio frequency heating did all this. The teaming of motion and electricity by Westinghouse engineers in this example paid off the original investment in 60 days!

Make kitchen utensils or build radio cabinets, it's all the same. Combine motion and electricity properly and you have a new production giant.

Want proof? Fourteen case histories in booklet B-3620A give you facts, cite figures, demonstrate how Westinghouse engineers blend motion and electricity to give you this production wizard. Write for it. It's an important contribution to production management. Westinghouse Electric Corporation, P. O. Box 868, Pittsburgh 30, Pennsylvania. J-02126-A

*Name on request

YOU CAN BE SURE .. IF IT'S
Westinghouse

Westinghouse
PLANTS IN 25 CITIES . . . OFFICES EVERYWHERE
R.F. HEATING

MORE PRODUCTIVE POWER FOR INDUSTRY

Drop Forge Division Operations

WILLYS-OVERLAND MOTORS, INC.

Emphasize Speed of GAS

SPEED HEATING of small billets for drop forging demonstrates the speed of GAS for production-line operations requiring a flexible, controllable fuel.

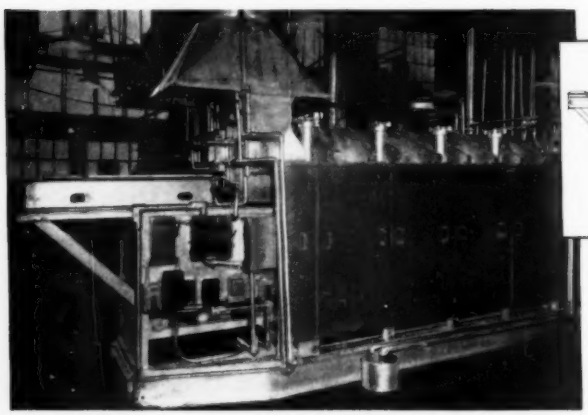
Drop Forge Division engineers and metallurgists, working with the furnace manufacturers, devised a simple Gas-fired, continuous-cycle billet furnace with the following characteristics and capabilities:

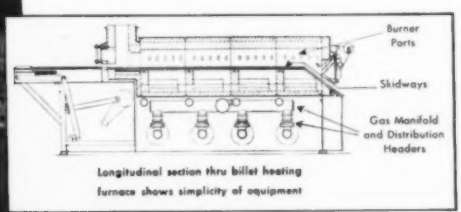
- **Billet Temperatures—2,200°-2,300°F**
- **Billet Heating Time—4 minutes normal (can be regulated as required in production schedules)**
- **Billet Discharge Rate—440 per hour, on 4-minute cycle**
- **Piece Dimensions (Average)—1"-2.5" thickness or diameter for rounds, squares, or flats up to 10" in length**
- **Furnace Heat-up Time—2,500°F in 15 minutes after initial lighting**

Quite as important as the productive capacity of the furnace are results of high-speed billet heating with GAS—

- **Uniform temperature of billets improves workability in forge**
- **Reduced scale minimizes abrasion in dies**
- **Flexibility for different sizes and shapes without costly equipment changes**
- **Economy of operation, of fuel costs, and of equipment investment**

This application of modern Gas Equipment in an important production-line process is just one of the contributions made by GAS to industrial progress. There are many other heat-processing operations such as annealing, normalizing, stress-relieving, case-hardening, in which the productive flames of GAS have established records for productioneering. They're worth investigating.



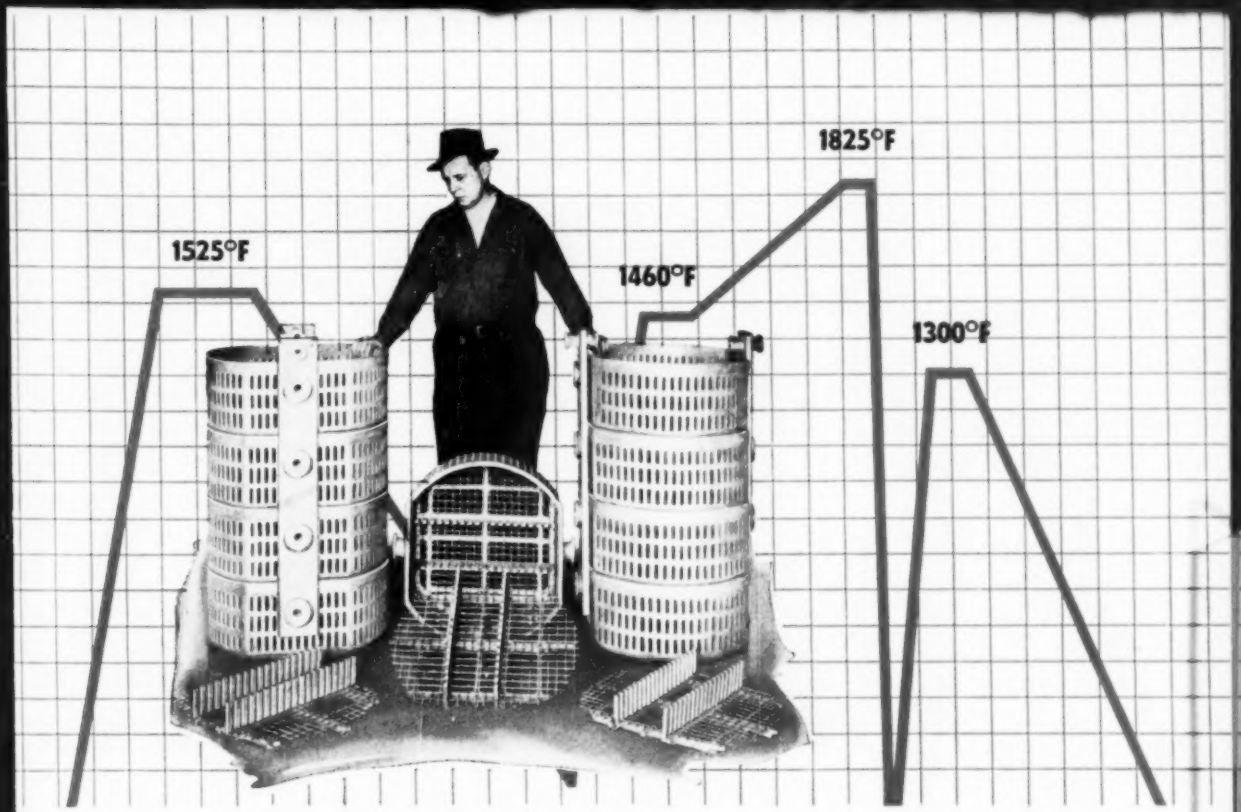


Longitudinal section thru billet heating furnace shows simplicity of equipment

Section Drawing courtesy of Surface Combustion Corporation, Toledo, Ohio, manufacturers of the billet heating furnace.

AMERICAN GAS ASSOCIATION

420 LEXINGTON AVENUE NEW YORK 17, N. Y.



You can give NICHROME* terrific punishment ...and still get low heat-hour costs!

Here, for example, is what we mean: These baskets and fixtures, used for hardening stainless steel impeller blades during heat treating operations, *must stay on the job* despite punishing cycles and high-rate quenching.

The blades are first annealed, in a pit type furnace, by heating them to 1525°F.; then cooled. Then they are hardened, by heating them to 1460°F. for half an hour, raising the temperature to 1825°F. for 10 minutes, and quenching. Finally, they are tempered, by reheating to 1300°F. and cooling in the furnace. And this goes on continuously.

Faced with the problem of obtaining heat-treating equipment that could "stand the gaff" day in and day out, York Corporation, of York, Pa., adopted fixtures and baskets of Nichrome—designed and cast by Driver-Harris.

The superb heat and corrosion-resistant properties of Nichrome, assuring long life and dependable service under such punishing conditions, have enabled these baskets and fixtures to remain in operation for over a year without any need for repair. In addition, the lighter construction made possible by Nichrome has reduced deadweight—resulting in higher heat transfer and less heat consumption. Result: Low *heat-hour costs.*

If your heat-treating problem is as tough as this one, and you would like better results, Nichrome is most probably the the right answer; if it is of the "common or garden variety", Nichrome will give you phenomenally more efficient, economical and lasting service.

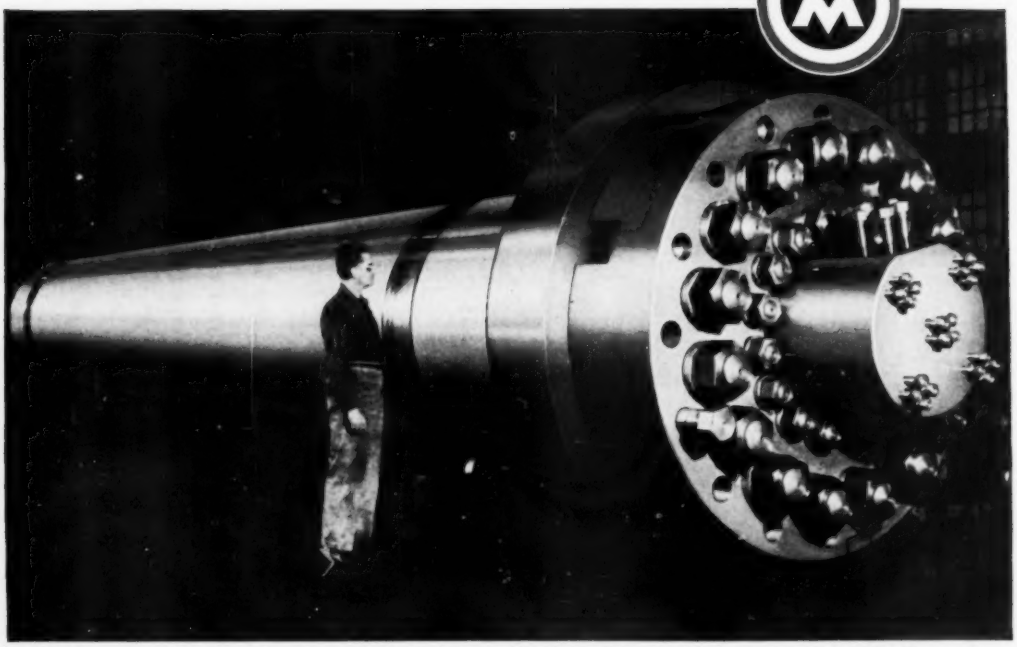
Nichrome is manufactured only by

Driver-Harris Company

HARRISON, NEW JERSEY

BRANCHES: Chicago, Detroit, Cleveland, Los Angeles, San Francisco, Seattle

*T.M. Reg. U. S. Pat. Off.



The chrome vanadium steel ingot from which this Pressure Vessel was forged weighed approximately 550,000 pounds.

LARGEST FORGED ALLOY PRESSURE VESSEL EVER MADE

Midvale makes one piece hollow Forged Pressure Vessels for the chemical, refining and process industries under the watchful eye of the Midvale quality control system. Midvale quality control starts with the design and is maintained through all operations to the finished product.

The big fellow pictured here, for instance, was inspected by trained engineers at every step of the way from design to pressure testing. Every Midvale forged pressure vessel, regardless of size, is so inspected and controlled, assuring safety and quality.

THE MIDVALE COMPANY • NICETOWN • PHILADELPHIA

OFFICES: NEW YORK • CHICAGO • PITTSBURGH
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MIDVALE

Custom Steel Makers to Industry

FORGINGS AND RINGS

•

CORROSION AND HEAT RESISTING CASTINGS

Perhaps our conservative attitude towards metal powder applications has discouraged many manufacturers from making use of powder metallurgy.

Naturally, we're sorry about this. But our established realistic policy of taking only the kind of business that results in lasting satisfaction for the customer remains unchanged.

We'd still rather lose an order than speculate with a manufacturer's time and money on the mere chance that powder metallurgy might work for him.

That's why we consistently emphasize the requirements for practical metal powder parts production. That's why we tell you that we can't honestly begin to accept your business unless the parts you need fulfill these conditions: (1) The shape permits good die fill and proper density; (2) the order is sufficiently large to justify initial tooling costs; (3) the physical properties and tolerances required are within the range obtainable in normal factory production.

MORAINE PRODUCTS

DIVISION OF **GENERAL MOTORS** DAYTON, OHIO

METAL POWDER PARTS . . . BY MORAINE

THE uniformity of the high quality steel used in the manufacture of Youngstown Cold-finished Bars results in excellent machinability. Youngstown's steel makers have had many years of experience in producing these steels to the specifications which are ideal for screw machine products and many other uses. Youngstown Cold-finished Bars are produced in a wide range of shapes and sizes--straight lengths or coils. Phone, write or wire the nearest Youngstown District Sales Office and ask a representative to call and discuss your Cold-finished Bar requirements with you.

QUALITY YOUNGSTOWN SERVICE

Youngstown

COLD FINISHED CARBON AND ALLOY STEEL BARS

THE YOUNGSTOWN SHEET AND TUBE COMPANY General Offices — Youngstown 1, Ohio

Manufacturers of Carbon, Alloy and Yoloy Steel Export Office - 500 Fifth Avenue, New York

COLD FINISHED CARBON AND ALLOY BARS - SHEETS - PLATES - WIRE - TIE PLATES AND SPIKES - ELECTROLYTIC TIN PLATE - COKE TIN PLATE - PIPE AND TUBULAR PRODUCTS - CONDUIT - BARS - RODS.

WEIRTON

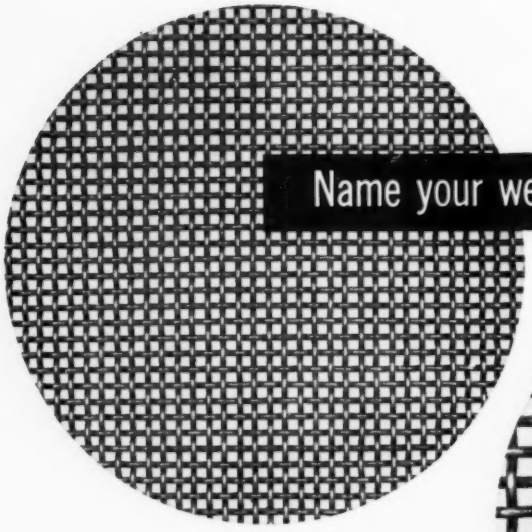
COLD-ROLLED STRIP

The use of Weirton cold-rolled strip steel can be a big factor in maintaining high volume at low cost in the making of countless articles or parts. Its exceptional drawing and forming qualities speed up and simplify production. Costs are cut because spoilage and scrap losses and tool expense are reduced. Plant efficiency and product efficiency are improved through standardization on Weirton cold-rolled strip steel.

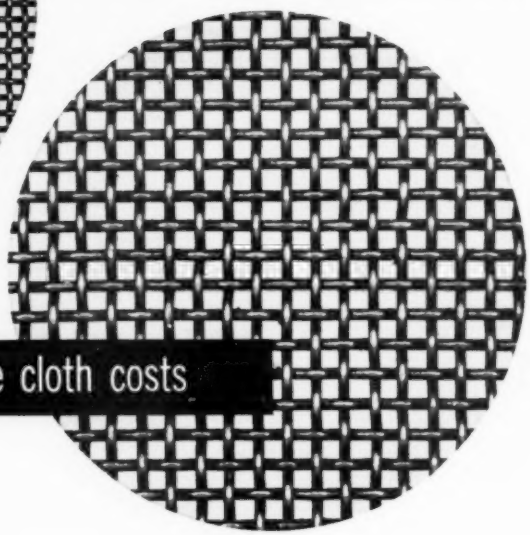
WEIRTON STEEL CO.

WEIRTON, W. VA., *Sales Offices in Principal Cities*

Division of **NATIONAL STEEL CORPORATION,** *Executive Offices, Pittsburgh, Pennsylvania*



Name your weave, your mesh, your metal



We can help you cut wire cloth costs

With manufacturing facilities on both the East and West Coasts, and engineering sales service in key cities throughout the nation, we can help you find the answers to your wire cloth problems.

Backed by 90 years' experience, our service to over 100 industries covers the precision fabrication of wire cloth in a dozen different coarse and fine weaves; in all commonly used metals; to withstand chemical action, corrosion, abrasion, moisture, or high temperature.

Whether you use wire cloth for screening, filtering, grading, cleaning, or processing, you'll find Wissco and Calwico Wire Cloth will give long, dependable service.

Super-Tempered PRECISION SCREENS

Even under excessive vibration these screens won't wear loose in service. They're made of tough, super-tempered steel and woven on new modern power looms. Wissco and Calwico Super-Tempered Precision Screens stay tight and accurate throughout a long life. Any length required for vibrating screen or trommel can be furnished with welded, hooked, or reinforced edge to fit any type of vibrator. Write for details.

WISSCO *Wire Cloth* **CALWICO**

East of the Rockies it's **WISSCO**
WICKWIRE SPENCER STEEL
STERLING ST., CLINTON, MASS.

CF&I

CALWICO *On the Pacific Coast*
THE CALIFORNIA WIRE CLOTH CORP.
1080—19TH AVE., OAKLAND, CAL.

How ELECTROMET Serves the Steel Industry

IN addition to providing a full line of high-quality ferro-alloys and alloying metals, Electro Metallurgical Division serves steelmakers in other important ways:

Field Metallurgists — You can obtain the help of our trained metallurgists who render on-the-job assistance in the use of ferro-alloys. These men are qualified to suggest the grades and sizes of alloys best suited for your particular steel and practice.

Laboratory Research— You can benefit by the new alloys developed by our continuous laboratory research. Developments from this research include the low-carbon ferro-alloys, silicomanganese, SILCAZ alloy, calcium metal, calcium-silicon, and ferrocolumbium.

Experience—Our store of information about ferro-alloys and their use, based on over 40 years' experience in producing them, is available to the steel industry.

Technical Booklets—You will find helpful information about ferro-alloys and metals in ELECTROMET's free technical booklets and reprints. Among these are "ELECTROMET Products and Service" and "ELECTROMET Ferro-Alloys and Metals." Write to our Technical Service Department to obtain copies of these booklets.

Convenient Facilities— You can count on prompt and efficient service from ELECTROMET, since our offices, plants, and warehouses are conveniently located to serve you.

ELECTROMET Ferro-Alloys and Metals

Information about these and other alloys and metals produced by ELECTROMET is contained in the booklet, "ELECTROMET Products and Service." Write for a copy.

CHROMIUM . . . Low-Carbon Ferrochrome (in all grades from 0.03% maximum to 2.00% maximum Carbon), Nitrogen-Bearing Low-Carbon Ferrochrome, High-Carbon Ferrochrome, SM Ferrochrome, Chromium Metal, CMSZ Mix, and other Chromium Alloys.

VANADIUM . . . Ferrovanadium in all grades, Vanadium Oxide, and Ammonium Metavanadate.

COLUMBIUM . . . Ferrocolumbium.

MANGANESE . . . Standard Ferromanganese, Low-Carbon and Medium-Carbon Ferromanganese, Low-Iron Ferromanganese, Manganese Metal, and other Manganese Alloys.

SILICOMANGANESE . . . Max. 1.50 and 2.00% Carbon Grades.

TUNGSTEN . . . Ferrotungsten, Tungsten Powder, and Calcium Tungstate Nuggets.

BORON . . . Ferroboron, Manganese-Boron, Nickel-Boron, and SILCAZ Alloy.

SILICON . . . Ferrosilicon in all grades including both regular and low-aluminum material, Silicon Metal, SMZ Alloy, and other Silicon Alloys.

TITANIUM . . . Silicon-Titanium and Manganese-Nickel-Titanium.

CALCIUM . . . Calcium-Silicon, Calcium-Manganese-Silicon, and Calcium Metal.

"EM" BRIQUETS . . . Silicon, Silicomanganese, Ferromanganese, and Chromium Briquets.

ZIRCONIUM . . . 12-15%, and 35-40% Zirconium Alloys, and Nickel-Zirconium.

"CMSZ," "Electromet," "EM," "Silcaz," "SM," and "SMZ" are trade-marks of Union Carbide and Carbon Corporation.

ELECTROMET Ferro-Alloys and Metals are sold by Electro Metallurgical Sales Corporation. Offices: Birmingham—Chicago—Cleveland—Detroit—New York—Pittsburgh—San Francisco.

Electromet
Trade-Mark
Ferro-Alloys and Metals

Electro Metallurgical Division
Union Carbide and Carbon Corporation
30 East 42nd Street UCC New York 17, N. Y.
In Canada: Electro Metallurgical Company of Canada, Limited, Welland, Ontario

1/10 second to wink...

1/50 second is average shutter speed..

NOW you can catch all speeds from 1/10,000 to 3 seconds

WITH THIS TIME INTERVAL METER

How to determine the speed of camera shutters as they rolled off the production line? How to do it quickly and accurately?

That was the problem faced by Graflex, Inc., of Rochester, N. Y. The method formerly used to determine these speeds was to take photographic exposures of the shutters in action. This accomplished the quality-control test satisfactorily. But it was slow and expensive! And the job was a manual operation. In the second place, developing the film took time!

The problem was given to General Electric. The result was a time interval meter . . . an instrument that measures time interval speeds 1000 times faster than the wink of an eye.

This gave Graflex a new quality-control instrument . . . an instrument that did the job faster and saved money.

But its use didn't stop here. Many of these equipments soon found their way into other industries . . . industries where the problem was measuring time intervals.

General Electric engineers have helped solve thousands of such problems for industry. Frequently, the result has been a new testing and measuring equipment. Equipment that today is saving time and money for industry!

Your problem may justify a development program to create a new product, particularly if the problem is a common one. Or, maybe, our engineers can recommend an instrument from the many testing and measuring equipments already available . . . proved equipments that are doing jobs on problems similar to yours.

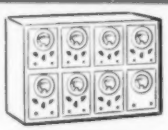
Write us about your problem. Maybe we can help you.

Apparatus Dept., Section H800-42,
General Electric Co., Schenectady 5, N. Y.

General Electric testing and measuring equipments for nearly every industrial process

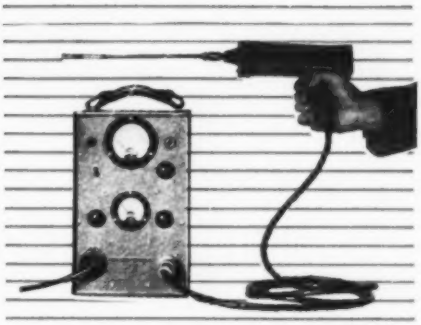
Resistance and Insulation Testing Equipment

Time, Speed and Torque Equipment



Force, Strain and Thickness Gages

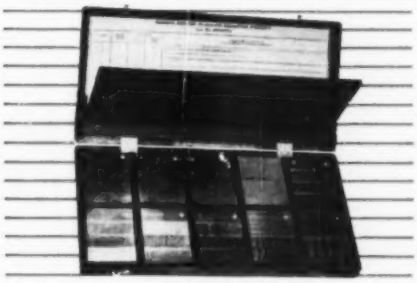
LEAK DETECTION . . . How new portable unit cuts production testing time . . .



This portable G-E Leak Detector has proved such a time saver for quality-control testing of pressurized systems for leaks that one manufacturer is already using over 30 of the units on his production line. Another just placed his order for 20.

So sensitive it can detect a leak which would permit the escape of only 1/100 of an ounce of freon in one year . . . yet entire equipment only weighs 18 pounds. Designed for locating leaks in refrigerators, home freezers, air conditioners, or tanks, boilers, piping and other closed systems into which Freon or some other halogen compound can be introduced as a tracer. Write for GEC-233A.

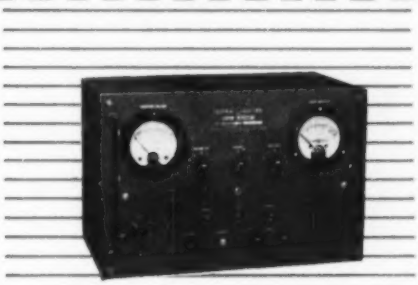
SURFACE TESTING . . . with this kit you can check 25 degrees of surface finish . . .



Ideal for engineers, draftsmen, machine operators, inspectors, etc., for specifying and inspecting finish or roughness of machined parts. Kit provides standard roughness specimens ranging from smoothness of bearings to roughness left by a flame cut. These specimens consist of a set of metal blocks, each representing a degree of surface roughness.

Simple to use! Tests can be made either visually or by the sense of touch. Thus, little or no experience is required to put the standards into operation. Write for GEA–4335.

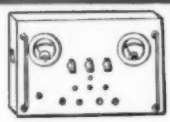
CHEMICAL ANALYSIS . . . mercury-vapor detector tracks down dangerous fumes . . .



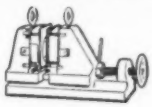
Severe and difficult symptoms make "mercurialism" (poisoning from mercury vapor) hard to detect. That's the reason many laboratories, factories, and 13 state health departments use the G-E mercury-vapor detector to diagnose these fumes and thereby provide adequate safety measures.

Enclosed in an attractive, gray-steel case, this instrument is portable, lightweight and easy to operate. Its ability to indicate concentration of mercury vapors in a few seconds makes it ideal for either laboratory or factory. You can use wherever 115-volts, 60-cycle power is available. Write for GEA-4390A.

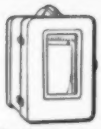
Color, Light and Spectro Equipment



Chemical Analysis Equipment



Magnetic Equipment

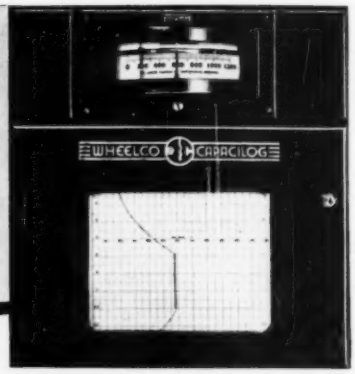


Electric Circuit Testing Equipment

Vibration, Sound and Balancing Equipment

GENERAL ELECTRIC

IMPROVE *Your Production* PROCESS...



With these Simple and Accurate Instruments
For Measurement, Control and Permanent Record

CAPACILOG STRIP-CHART RECORDER
Request Bulletin C2

FOR PREDETERMINED TIME CYCLE CONTROL

WHEELCO CHRONOTROL
Request Bulletin D2

FOR ELECTRONIC CONTROL OF PROCESS VARIABLES

PANELMOUNT CAPACITROL

More than 40,000 Capacitrols on process applications attest the reliability of this instrument. Capacitrols operate on the well known Wheelco "Electronic—no contact—Principle". Request Bulletin D2.

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FLAME-OTROL FOR GAS AND OIL
Request Bulletin F1

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PORTABLE POTENTIOMETER
Request Bulletin A502

FOR MEASURING TEMPERATURES FROM 0° TO 3600°F

INDICATING PYROMETER
Request Bulletin D302

FOR TEMPERATURE SHUT-OFF AND OVERHEATING PROTECTION

SURFACE TYPE LIMITROL
Request Bulletin D202

Whether your process requires brazing, nitriding, carburizing, galvanizing, die casting, powder metallurgy, forging, bright hardening, cyaniding or low frequency heating there is a model for your purpose. These instruments are extremely accurate, with a simple plug-in design—easy to operate.

Consult your Wheelco Representative or write to the factory for descriptive literature.

WHEELCO INSTRUMENTS COMPANY
835 West Harrison Street • Chicago 7, Illinois

WHEELCO *Electronic* CONTROLS

RECORDERS • COMBUSTION SAFEGUARDS • CONTROLLERS

A-H5

(5 PCT CHROME AIR-HARDENING)

A-H5 combines the safety of air-hardening with excellent resistance to distortion. It is deep-hardening in large sections and has high resistance to shock and wear. Shown is a ring gauge made of A-H5.
P-4117-5

An air-hardening tool steel *that's easy to machine*

Air-hardening tool steels are the best choice for many tools and dies, but the more highly-alloyed of these grades often present machining problems. Toolmakers like A-H5 because this lower-alloy type is annealed to 212 Brinell or less for easy-machining, yet provides the great safety of air-hardening.

A-H5 is recommended for the same tool and die jobs where you are using the standard oil-hardening tool steels such as BTR (Bethlehem Tool Room). A-H5 is of course the choice when a relatively drastic quench in oil is not permissible. And it is preferred when you need deeper hardening, greater resistance to distortion, and higher wear-resistance for cutting edges.

Use A-H5 for dies, punches, blanking tools, cold-forming dies, master tools and the like. Give it a thorough trial and you'll agree that it belongs in your tool room. The nearest Bethlehem sales office or tool steel distributor will gladly give you full details and arrange for prompt delivery.

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation
Export Distributor: Bethlehem Steel Export Corporation

QUICK FACTS ABOUT A-H5

Typical Analysis:	C	Mn	Cr	Mo	V
	1.00	0.60	5.25	1.10	0.25

Annealing: Pack, heat to 1650 F, slow furnace-cool, Brinell 212 max
Preheating: 1200 to 1250 F, prior to hardening
Hardening: 1775 F, air-quench
Tempering: 350 to 400 F, Rockwell C 60 to 62

★ BETHLEHEM STEEL ★

A-H5 ...one of Bethlehem's fine tool steels

It's MISCO for HEAT RESISTING ALLOYS IN ROLLED MILL FORMS

Sheets — Plates ▬ Rounds ● Squares ■ Hexagons ⬢ Flats ▬ Angles L
Channels U Sections ⌐ Pipe ○ Nuts ⬡ Welding Rod

WHENEVER YOU NEED ROLLED HEAT RESISTING ALLOYS CONSIDER THESE MISCO ADVANTAGES

1 *Select* the ALLOY that does YOUR job best. These job-proven Misco Heat Resisting Alloys (in stock) offer you a correct alloy analysis for every condition of high temperature service . . .

MISCO METAL	A.I.S.I. TYPE 330	36 NI—16 CR
MISCO K	A.I.S.I. TYPE 310	20 NI—25 CR
MISCO B	A.I.S.I. TYPE 309	14 NI—23 CR
MISCO 430	A.I.S.I. TYPE 430	17 CR

When buying from Misco you are not limited to one general purpose alloy only.

2 **DELIVERY**—Within 3 days. Over 200 items in warehouse stock—more in process for direct mill shipments. Send now for up-to-date monthly stock list.

Cut down overhead—let Misco be your warehouse.

3 **COST**—Regular published mill Stainless prices apply to warehouse shipments—with minor exceptions.

You don't pay "Speciality Alloy" high prices to Misco.

4 **QUALITY**—Rigid quality control based on our experience as the largest exclusive heat resisting alloy distributor, regularly dealing with hundreds of customers, in many diversified industries, located in every part of the United States.

Send your alloy orders to Misco.

Sheets
Plates
Rounds
Squares
Hexagons
Flats
Angles
Channels
Sections
Pipe
Nuts
Welding Rod

ROLLED HEAT RESISTING ALLOYS

ROLLED PRODUCTS DIVISION
Michigan Steel Casting Company

MISCO
Heat and Corrosion Resistant Alloys

One of the World's Pioneer Producers and Distributors of Heat and Corrosion Resisting Alloys

1998 GUOIN STREET • DETROIT 7, MICHIGAN

The Foreman of this progressive shop (left) consults with a Gulf Lubrication Engineer on results with Gulf L.S. Cutting Base in machining clock parts.

Costs Down-Production Up!

"We've sharply reduced time per piece, improved surface finish, and greatly extended the number of pieces per tool grind since we switched to Gulf L.S. Cutting Base," says this Foreman of Main Screw Machine Products, Inc., Waterbury, Conn.

"On our new ¾" automatics we are performing two turning, one threading, and one cut off operation on a steel clock part at the rate of 1.2 seconds per piece. With the cutting oil we used previously the time per piece was much higher."

"Just as important to us has been the increased number of pieces per tool grind. With Gulf L.S. Cutting Base we are now running 16,000 pieces before regrinding of the tools is necessary. Add the fact that we are getting better finishes, and you can see why we're gratified by our experience with this fine cutting oil."

Here's another example of how the proper application of the right Gulf quality cutting oil improves production and lower costs. To make sure that you're getting all the benefits possible through the use of more suitable cutting oils, call in a Gulf Lubrication Engineer today.

Gulf Oil Corporation · Gulf Refining Company

Division Sales Offices:

Boston · New York · Philadelphia · Pittsburgh · Atlanta
New Orleans · Houston · Louisville · Toledo

GULF INDUSTRIAL LUBRICATION

Gulf Oil Corporation · Gulf Refining Company MP
3800 Gulf Building, Pittsburgh 30, Pa.

Please send me, without obligation, a copy of your pamphlet "The new improved Gulf L.S. Cutting Base."

Name.....

Company.....

Title.....

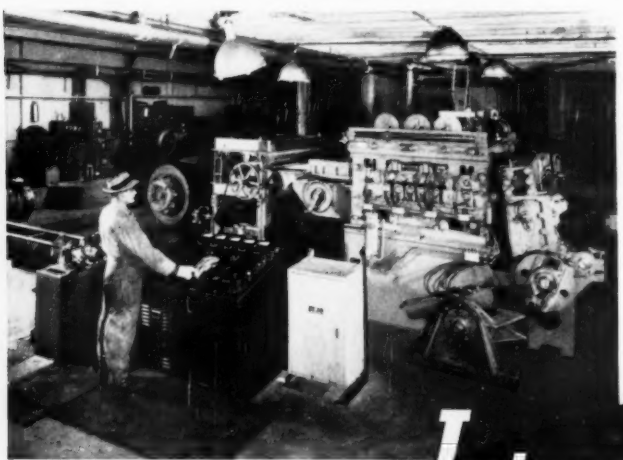
Address.....

HE IS DOUBLY SERVED WHO GETS HIS STEEL, and GETS IT... when he wants it

International has helped many manufacturers meet their supply problems by providing dependable service in de-coiling, flattening, cutting, and pickling, or by coil slitting.

Here you will find such equipment as is used by the mills . . . the most modern, independent setup of this kind in the Midwest.

International — like everyone — has none too much steel. But, if you have available tonnages of hot rolled coil, International can process it for you on a basis that will assure a dependable, steady supply . . . and, perhaps, save you money. Ask about our service.



International's Flying Shear de-coils, flattens, cuts accurately to length. Coil slitter may be seen in background.

STEEL I SERVICE INTERNATIONAL

International

ROLLING MILL PRODUCTS CORPORATION

5033 S. KEDZIE AVE., CHICAGO 32, ILL. Phone HE 4-5200

Analyze the whole Picture...

When you select Cutting Fluids

IN SELECTING cutting fluids for your machining operations consider your choice from every angle. Will it increase production? Will it lower production costs? Will it improve finish? Will it meet all other requirements peculiar to your operation?

When you look at the whole picture you'll want to investigate the advantages to be gained by specifying the dependable, service-proved cutting fluids of Cities Service. Such products, for example, as Cities Service Chillo Oils which have been performance tested in scores of machine shops.

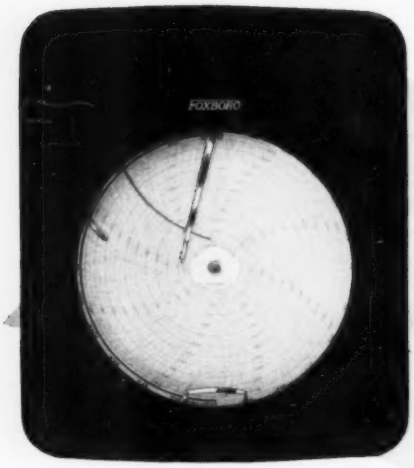
Why not let a Cities Service cutting oil specialist help you select the best type and grade for your purpose? His recommendations may bring you substantial improvements in the quantity and quality of your production.

Free

Write today for our new and informative booklet entitled "Metal Cutting Fluids". Address Cities Service Oil Co., Room 307, Sixty Wall Tower, New York 5, N. Y.

CITIES SERVICE

UNIQUE *SPEED* OF BALANCING



Full scale to complete balance in as little as one second* without wear.

because this Potentiometer has no Slidewire

The almost instantaneous speed of Dynalog** Potentiometers is the result of an entirely new concept in potentiometer design. *The usual slidewire is replaced by a simple, variable, radio-type capacitor.*

This advanced balancing device is so simple, so direct, so friction-free, that it responds almost instantly. No fast-moving parts . . . no moving contacts, gears, cables or other complicated mechanisms to slow it up or develop backlash . . . no turn-to-turn steps of slide-wire winding! Its power drive, operated by electronic amplification of bridge unbalance voltage, provides automatic, continuous, *stepless* balancing without over-shoot.

Dynalog Instruments are available for measuring or controlling temperature (with thermocouples or resistance bulbs), humidity, pressure, flow, force, etc. Get facts in Bulletin 427. Write **The Foxboro Company, 52 Neponset Avenue, Foxboro, Mass., U. S. A.**

**5 seconds standard* ***Reg. U. S. Pat. Off.*

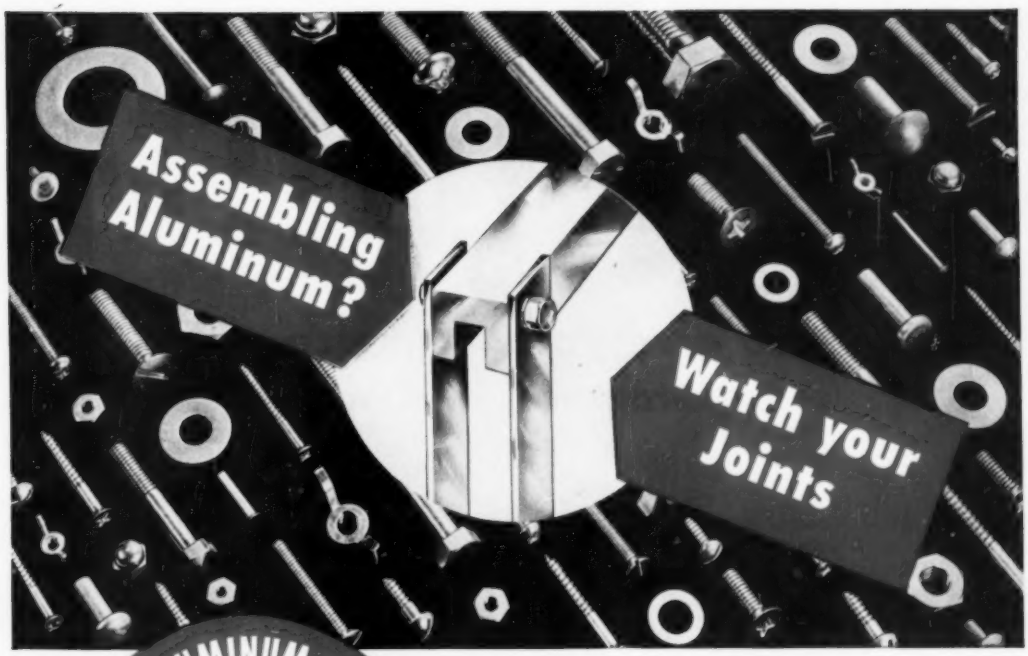
This smooth-operating radio-type capacitor takes the place of the conventional slide-wire. Gives continuous STEPLESS balancing!

OTHER DYNALOG FEATURES

- **SENSITIVITY** . . . one ten-thousandth of scale (1/100 of 1%).
- **ACCURACY** . . . 1/400, or ¼ of 1% of scale.
- No galvanometer.
- No batteries to standardize.
- No periodic maintenance.
- No knowledge of electronics needed.

FOXBORO
Reg. U.S. Pat. Off.

DYNALOG *ELECTRONIC* **INSTRUMENTS**



SPECIFY ALCOA FASTENERS

. . . right on your drawings

Galvanic corrosion can weaken joints—spoil your product's performance—if you assemble aluminum parts with fasteners made of a dissimilar metal! Keep all of the advantages of your aluminum product *throughout*—make assemblies with Alcoa Screws, Bolts and Nuts, or Rivets.

Every type you need is included in the complete Alcoa line. They're strong, good looking, made to Alcoa quality standards. Yet not expensive.

WRITE FOR FREE SAMPLES

of the types that interest you. And phone your nearest Alcoa sales office or Alcoa distributor for prompt service. ALUMINUM COMPANY OF AMERICA, 2101 Gulf Building, Pittsburgh 19, Pa.

ALCOA

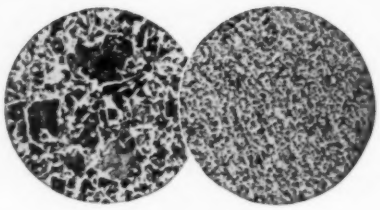
ALCOA *Aluminum* FASTENERS

YOU CAN DEPEND ON

VANADIUM

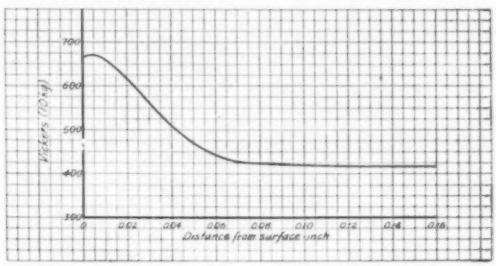
to give you grain size control, high performance, and ease of processing

GRAIN SIZE is refined by the addition of vanadium, the balance between strength and toughness is improved, and greater uniformity is promoted between transverse and longitudinal properties.



0.34 C 0.34 C, 0.20 V

HIGH PERFORMANCE follows the use of vanadium in constructional steels. In carburized parts, for example, the well-integrated bonding between case and core, inherent in vanadium carburizing steels, assures excellent shock-resisting properties and maximum service life.



Hardness penetration graph of Chromium-Vanadium A 6120 steel, with a light case (0.80–0.85% carbon) in outer .010 inch

EASE OF PROCESSING—Uniformity of vanadium steels from heat to heat, with easy and uniform response to thermal and mechanical treatments, brings large compensation—savings far over-shadowing differences in initial materials costs.

Our metallurgists will be glad to assist you in the application of vanadium to meet your requirements.

MAKERS OF FERRO-ALLOYS VANCORAM CHEMICALS AND METALS

VANADIUM CORPORATION OF AMERICA

420 LEXINGTON AVENUE, NEW YORK 17, N. Y. • DETROIT • CHICAGO • CLEVELAND • PITTSBURGH

DRAPER CORPORATION world's largest loom manufacturer

LOWERS PRODUCTION COSTS WITH

J & L COLD-FINISHED JALCASE STEEL

J&L STEEL

Mr. Joseph Whalley holds a shuttle from a modern Draper high-speed rayon loom to show the Jalcase tips.—Demonstration Room in Draper Corporation's modern plant, Hopedale, Massachusetts.

Shuttle Tips* made of JALCASE last longer . . . are easier to machine and heat treat.

Most likely the fabric in your broadcloth or oxford shirt was woven on a Draper loom, because Draper Corporation is the world's largest manufacturer of cotton and rayon looms. —And on many of the shuttles in these famous looms, the tips are made from J&L COLD-FINISHED JALCASE, the *original* open-hearth free-machining steel.

These tips must withstand *millions* of blows from the "pickers" that send the shuttle flying back and forth across the loom as many as *225 times a minute*. The steel must have uniform heat-treating characteristics to produce tips with *hard* points, *soft* shoulders and *tough* stems. Besides, Draper wants a steel that machines freely to a smooth finish at high speeds, and a steel that conserves tool life. That's why Draper uses J&L COLD-FINISHED JALCASE. It reduces production costs!

Here is a steel that is practically "tailor-made" to your requirements. From the ten grades of JALCASE, you can select just the right properties that suit *your* manufacturing conditions best. The result is: Higher production . . . Longer tool life . . . A better product. No wonder that J&L COLD-FINISHED JALCASE has been the *leading free-machining steel* for more than 25 years!

We have just published a new booklet describing the ten grades of J&L COLD-FINISHED JALCASE Steel. Let us send you a copy. It's free. The coupon is for your convenience.

Jones & Laughlin Steel Corporation
405 Jones & Laughlin Building
Pittsburgh 19, Pennsylvania

Please send me your new booklet on J&L COLD-FINISHED JALCASE — the *original*, open-hearth, free-machining steel.

NAME_____

ADDRESS_____

JONES & LAUGHLIN STEEL CORPORATION

From its own raw materials, J&L manufactures a full line of carbon steel products, as well as certain products in OTISCOLOY *and* JALLOY *(hi-tensile steels).*

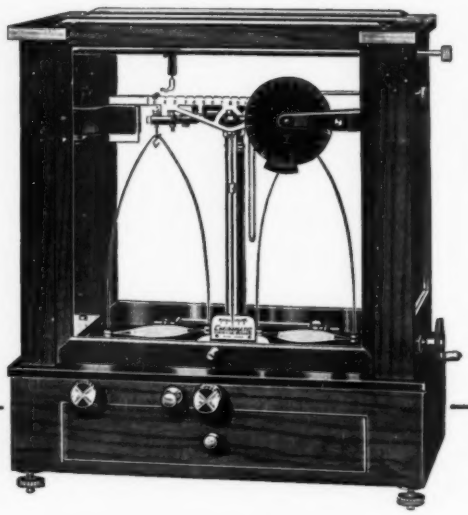
PRINCIPAL PRODUCTS: HOT ROLLED AND COLD FINISHED BARS AND SHAPES • STRUCTURALS AND PLATES • HOT AND COLD ROLLED STRIP AND SHEETS • TUBULAR, WIRE AND TIN MILL PRODUCTS • "PRECISIONBILT" WIRE ROPE • COAL CHEMICALS

Christian Becker Balance

★ MODEL 1415 ★

For Precision Weighing

- ★ *Readings at constant eye level and from a fixed point*
- ★ *Freedom from parallax error*
- ★ *Less eye strain*
- ★ *The right pan is more accessible*



The Christian Becker Model 1415 Balance is a fine, precision instrument for general laboratory use. It is a Chainomatic balance (dial reading), has graduated notched beam, and is magnetically damped.

No weights are required from 1/10 mg. to 1.1 gram. These balances are equipped with Movable Index or "Auto-Dex" and Equilibrium Adjuster.

Capacity—200 grams

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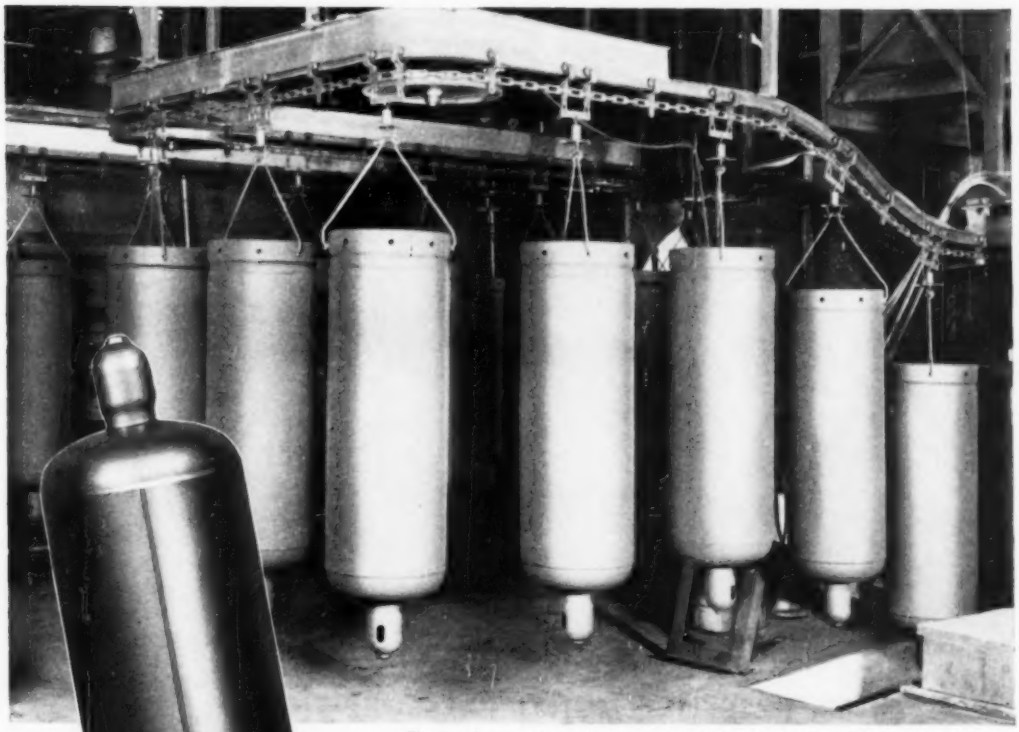

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METAL PROGRESS

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RYERSON STEEL

THE STEEL INDUSTRY IN TRANSITION

By the Editor

THE Lake Superior region, as all know, is where the cheap iron ore comes from that supplies the blast furnaces which support the American steel and foundry industry. The cheapest of this ore is steam shoveled from open pits; production from open pits is most easily and quickly expanded; the open pits indeed were our emergency supply during the last war. The open pits are true bonanzas, but everybody knows that any mine, no matter how rich and large, is eventually exhausted. Apparently, many important factors in the iron ore trade have suddenly awakened to the fact that the Mesabi open pits, with 600,000,000 tons of ore now in reserve, will be mined out at the present rate in about 12 years. Of course that does not mean that mining will stop, for about an equal quantity of proven ore exists underground in the Lake region, and there is a chance that other important surface deposits can be developed — as the recent one at Steep Rock, across the line in Canada. Likewise the figure for ore reserves is fictitiously small, for the Minnesota plan of taxing proven ore in the ground tends to discourage exploration and encourage rapid mining.

Ore, in the above sense, means red rock that contains 51.5% iron and 8.5% silica — proportions which have been maintained steadily for many years, although with an ever-increasing percentage of washed ore. One quarter of the entire tonnage is now "concentrated", in that sense, most of it by simply stirring up in a stream of water which carries out the fines, relatively lean in iron oxide. A small amount of ore is also enriched by methods well known to Western mill men, wherein the coarse sizes are put through jigs and the richer ore particles are separated from the leaner gangue by differences in specific gravity, the heavier portion settling down through pulsating water currents.

Consequently there has been no doubt but that methods used for lead, zinc and copper sulphide ores are applicable to the Minnesota iron oxide ores, even the soft surface ore with a preponderance of fines. Also a small mill has been working on the economics of the flotation methods now used universally for finely disseminated sulphide ores. It is certain that flotation is applicable to iron oxide ores, at a price. The wider use of such well-known concentration methods has been prevented by the availability of cheap, first-class ore — direct smelting ore, so to speak — in such huge quantities, both from open pit and underground operations.

Those readers of *Metal Progress* who know a little about milling will undoubtedly be interested in the unique "sink and float" method that has received so much engineering attention on the Iron Range. The iron oxides have a specific gravity somewhat greater than 3.0, whereas the silicate minerals constituting the gangue or country rock have a specific gravity somewhat less than 3.0. If, then, a mixture of oxide and silicate particles were merely fed into a quietly moving stream of some liquid three times as dense as water, the silicates would float off with the overflow and the iron oxide settle to the bottom.

This has in fact been done on a modest scale for some years. The ore is crushed to 1¼ in. and the $\frac{3}{16}$-in. and finer sizes screened out. (These fines continue to present a problem.) The fluid is a water emulsion of 14% ferrosilicon, ground to 65 mesh. 14% ferrosilicon is suitable despite its high price because it is noncorrosive and withstands abrasion; more than that, it is ferro-

The rapidly approaching exhaustion of open-pit mines on the Mesabi range leads the Editor to comment on the future sources of ore for the American steel industry. Since the proportion of washed ore to direct shipping ore has been continually increasing, and since the methods universally used for beneficiating nonferrous ores are quite applicable to the iron ores, he foresees a period of rapid and large development of ore concentrators — even though this might well be an expedient during the transition period while the entire steel industry is relocated so as to use, economically, new sources of ore.

magnetic so it can be almost completely reclaimed from the nonmagnetic hematite concentrates and the silicate tailings.

The above facts about ore dressing are not news to mining men in the Superior district. The proportion of washed ore to total shipped has been steadily growing for the last 30 years. This trend proves without doubt that if enough ore suitable for present-day blast furnace operations is to come from the Lake Superior region, it will require more and more concentration of off-grade ore, too low in iron or too high in silica to be marketable as mined. The catch in the situation has been that *any* treatment of ore costs money. Not only that but the amount of off-grade ore analyzing reasonably close to the present shipping limits is strictly limited. The really big reserves are in the country rock called taconite which geologically is the source of the present ore bodies. Enormous quantities of these taconites contain about 30% iron (seven eighths of which are particles that can be recovered by magnetic separation). The obvious importance of these taconites has warranted extensive study by Minnesota's Mines Experiment Station on the state university campus, and an interesting summary of the work was given the Editor recently by ⊜ member Henry H. Wade, chief metallurgist.

Magnetic concentration of fine-ground taconite was a failure in the early 1920's, despite a well-financed and large-scale effort at Babbitt, Minn., by men versed in Western concentration practices. Wade says the mining methods have now been greatly improved. Taconite will grind as easily as porphyry copper ore, but is very hard to drill and blast. Furthermore the concentrate was far too high in silica (12%), and the sintering equipment was very poor. (Even as yet, sintering of fine magnetite — as it is done, for example, in large tonnage on Adirondack magnetic concentrates — costs about $1.25 per ton.)

In the intervening years the taconite hasn't got any softer, but drilling methods — especially the drill steel and its heat treatment — have improved greatly. Open pit ores require a little blasting but considerable overburden must be removed; taconite needs dynamite but great quantities of it are at the grass roots. How this will balance out is problematic, but the cost of mining one ton of taconite in a large open pit should be on the same order of cost as the mining of hematite, and considerably less than the cost of underground ore mined in such great quantity in the Lake Superior region. However, 2½ tons of taconite are required for one ton of high-grade concentrate.

Concentration of the taconite has not yet started, except in an experimental way. There is no question but that good recoveries can be had. Furthermore, magnetic concentration is as simple as any Western flotation flow sheet — fine grind and separate the particles of magnetite from the gangue on magnetized belts or drums. All this is done wet. Eventual costs on a large scale should also be on the order of those at large Western concentrators handling 50,000 tons of ore per day, or about as much as it costs to steam shovel the ore. The product is really high grade (64% iron, 8% silica) but it is still in the form of fine powder.

Henry Wade hopes that the high cost of sintering can be reduced by a recent discovery at Minnesota's experiment station — namely, that when the filter cake (de-watered fine concentrate) is fed into a simple rotating drum along with 2% of fine anthracite, it rolls up into small compact spheres that grow like snowballs, and come out quite strong and stiff. A belt conveyer takes them to the top of a shaft furnace, through which they settle, counter to an air current that burns the anthracite and bakes the balls into porous hard marbles.

Tentative cost estimates for all such operations have been knocked silly by recent increases in the cost of living and the doubled cost of erecting new plants, but the Editor estimates that it will cost about six times as much to put a ton of nodulized magnetite concentrate aboard a boat at a Lake Superior port as a ton of hematite from a Mesabi open pit. The spread between cost f.o.b.

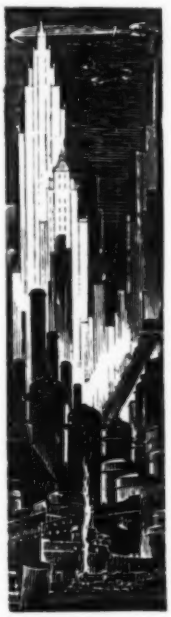
and selling price to the blast furnace, which includes taxes, royalties, transportation down the lakes, overhead and profit, should be about the same for each ton reaching the furnaces. If this spread is taken at $5 we have an anticipated cost of magnetite nodules (64% iron) at Lake Erie ports of at least $11 per ton as compared with $7 per ton of Mesabi hematite (51.5% iron).

Undoubtedly hard porous nodules of 64% magnetite are better blast furnace feed than dusty Mesabi hematite (51.5% iron), but not enough better to warrant the extra cost unless other important considerations are kept in mind.

First, proportionately less ore will be needed because of the higher analysis. Two tons of hematite ore are required for a ton of pig iron. The same amount of metallic iron is contained in 1.6 tons of nodules. The costs of ore, per ton of pig iron, would then be $18 for nodules against $14 for hematite, or an extra of $4. Supposing $1 were saved by economies in handling, faster production, dust recovery and the other items showing up when improving the quality of the blast furnace burden, we come out with an estimate of $3 extra cost of pig iron due to more expensive ore. In prewar days this extra would be unendurable. At present, with pig iron selling for $47 per ton, an increase of $3 would not seem so bad. That the proposition is commercial is proven by operations at the Benson mine of Jones & Laughlin Ore Co. in northern New York, which has steam shoveled 1,500,000 tons of ore in one year from which 600,000 tons of magnetite sinter were shipped 500 miles by rail to the Pittsburgh district, there to meet competition with Lake ore.

The staggering thing about it is the size of the necessary operation. It is the open pit ores in the ranges that must be replaced — 50 million tons a year — and within 12 years. The known underground deposits and operating mines elsewhere can expand production somewhat, but at best no more than to supply the expected normal increment of the steel industry's future expansion. The two enormous mills of the Utah Copper Co. south of Salt Lake City could handle only one eighth of this ore tonnage. Multiply all their requirements for water, for square miles of waste dumps, and consider means of reducing dust nuisances (even preventing silicosis) from great heaps of fine silica tailings, and the job looks immense indeed — just the thing for Americans.

But what are the alternatives?



"Cheap foreign ore, from Brazil or Chile, perhaps," may be the answer. Foreign ore is the answer for Bethlehem's Sparrows Point plant, of course. (At present, 68% Brazilian ore at 19½c a unit or $13.25 a ton at tidewater doesn't sound so very cheap.) Foreign ore may be all right in peaceful years, but it would be a dangerous reliance in wartime, as anyone knows who remembers how difficult it was for Germany to get iron ore from Sweden, or America to ferry bauxite across the Caribbean. How much will this "cheap foreign ore" cost us if we add the cost of naval or air fleets sufficient to guard the convoys? How much will it cost laid down at inland steel plants? How much will it cost if it requires our steel industry to relocate near the coast — something the strategists would certainly frown upon?

Since several important iron ore companies have recently started extensive ore dressing investigations, it seems that the attitude that new mines will replace the old has been abandoned. The present steel industry cannot safely tolerate rapid changes in supply of its principal raw materials. In coming years, more steel will doubtless be made near other important American ore bodies, as in Alabama or Utah, but this must be a gradual trend. Much hope is placed on newly discovered deposits in Labrador, some 300 miles north of the St. Lawrence. Their development is still for the future years, as is a connecting railway, and the canalization of the St. Lawrence itself — a billion dollar job. Until these mines replace the Mesabi open pits (if ever) a stand-by must be provided, because the present location and distribution of our industrial population, north of the Ohio and east of the Mississippi, means that the steel industry must remain about where it is; any change must be gradual.

The conclusion seems to be, therefore, that the Lake Superior region must continue to supply the lion's share of the iron ore for several decades, and the price of concentration will be the cheapest and safest alternative — a price, it is certain, that will go down in proportion to the sum total of the other steelmaking costs, as the years go by.

It means, in summary, that the American steel industry faces an economic change of great importance, and that no matter what the eventual new stabilized line-up will be, the transitional period must lean quite heavily upon iron ore concentration.

INTERGRANULAR WEAKNESS IN CARTRIDGE BRASS

By Fred M. Arnold
Director of Research and Development
Norris Stamping and Mfg. Co.
Los Angeles

LATE IN 1947, during the production of 3-in., 50-caliber brass cartridge cases for the Bureau of Ordnance, U. S. Navy, a few cases were found by the final inspectors with a "mark" on the inside surface of the head — a line in an arc part way around the primer boss. Upon cutting some of these cases, the heads were found to be ruptured midway between the surfaces. Also the inner layer was cracked at right angles to the main separation. This extended for various degrees of arc — 180° more or less — and was observable as a line on the inside surface of the head (Fig. 1).

This discovery was very disconcerting to us. Nothing even remotely resembling this condition had occurred during our manufacture of many million large caliber brass cases. All shipments were stopped.

The disks used in producing these cases were supplied by two sources which may be here referred to as Supplier X and Supplier Z. The disks in process at the time the defect was discovered were from Supplier Z.

A program was immediately undertaken to explore the nature and extent of the cracking. Heads were cut off and cut through on one or several diameters. The surfaces were etched, usually after some polishing, and the sections examined for cracks. A few cases with visible cracks were cut and extensive internal separations were found as in Fig. 1. Other cases, apparently sound but rejected from other causes during or after the tapering operation and made from metal from Supplier Z, were cut at random with the results tabulated at the top of the next column.

Number Cut	Number Cracked	Number Cored
60	14	6
250	8	–
50	← 27 →	

The coring mentioned in the last column in the above table often occurs in heavy-gage cartridge brass. Cored cases exhibit, after suitable polishing and etching, a pattern of markings especially toward the center of the section — an evidence of inhomogeneity arising during the solidification of the original ingot. It is also called dendritic segregation. Normally no harmful segregates are present in cartridge brass but the Reflectogage* rejected numerous cases from Supplier Z's brass which, when sectioned, showed only a marked coring.

That the difficulty was confined to brass from Supplier Z was proven by the fact that 59 of 62 cases made from disks from Supplier X were found sound and the three others developed only minute cracks after being strongly etched in nitric acid. These cracks were insignificant in extent and not intercrystalline, as in the defective heads. We would consider them to be of "normal" extent and frequency in any brass shipment.

*The Reflectogage is an instrument made by Sperry Products Co. of Danbury, Conn., for measuring thickness of sheet metal with inaccessible back surfaces. It sets up high-frequency oscillations in the metal and measures the response of the metal (its resonance) — a matter that is related to its thickness. We consider that its use in the inspection of cartridge cases is so important that a supplementary article on this test method will be presented in *Metal Progress*.

Fig. 1 — Appearance of the "Mark" First Observed on the Inside Surface of the Head, and the Extent of Cracking When Sectioned

It can be stated that the cases made from Supplier X did *not* exhibit any intercrystalline cracking through the heads or the peculiar microstructure found in the brass from Supplier Z.

The service conditions for this case require hardness in all parts of the head greater than previously required in the 3-in., 50-caliber case (which has been made since at least 1904). We developed a new tooling practice, based on our experience with steel cartridge cases,* for obtaining the required minimum hardness of Rockwell 30-T 67. These tools also eliminate all roughness in the radius (so-called "cold shut"). After the next-to-final draw the part is annealed and "preheaded" to gather metal for the primer boss and flange. The part is then final drawn and headed.

We wondered if this change from conventional tooling practice for brass cartridge cases, in which all the heading is done with flat bumpers after final drawing, could cause or contribute to the head separation — although we had produced eight million 3-in. steel cases using essentially this same practice. We studied the metal flow by inserting copper wires in holes drilled in the parts at various stages of processing (Fig. 2). We also scribed lines on the cross sections of preheads and noted their change due to heading. No locations of horizontal shear or offsetting occurred.

We modified the contours of this tooling to decrease any tendency to "lock" the metal. Many cases were cut and examined. We found nothing which indicated that our tooling was contributing to this internal bursting. Our annealing is all done at 1120° F. and stress relief at 500° F.; both practices are closely controlled.

During this testing of tooling, and using Supplier Z's disks, the following important observations were made:

1. Out of 18 cases made with conventional brass case practice and heading tools, one had a $^3/_8$-in. crack in the same relative location.

2. A preheaded case was cut and two cracks were found in the boss, as shown in Fig. 3.

3. Sixteen cases were preheaded, but final drawn with a punch without a recess for the boss; this caused the head to dome slightly. Two of these cases cracked seriously, circumferentially and with branches, as a result of final drawing only. The remaining 14 were headed, cut, and showed no cracks. The writer considers that these two cases exhibit the inherent defects which this brass suffers to as great a degree as any other, and that they should be useful in the study of the nature and possibly the cause of the defect.

These brass disks are produced at Supplier Z under Navy inspection. Analysis of each lot is made by the supplier. A review of the certified chemical analyses covering all these shipments shows:

	Maximum	Minimum
Copper	71.11%	69.86%
Lead	0.040	0.004
Iron	0.010	0.005
Tin	—	—
Zinc	Balance, by difference	

An obscure defect was recently found during the manufacture of 3-in., 50-caliber cases from cartridge brass. The cartridge brass disks were cut from hot rolled bars. The defective cases were confined to disks shipped from one brass mill. The defect was located in the center of the head section. Since there were no anomalies in composition or undue segregation of the solid chemical elements, it is possible that gas absorbed during melting and casting may be the cause — a possibility substantiated by experiments in the brass mill's casting department. The cause of the defect cannot be observed by microscopic examination, but the trouble can be cured by an appropriate annealing cycle.

*Described by the present author in *Metal Progress* for January 1945, p. 67.

All of these disks had a copper content above the range where "beta defect" might be experienced. (See "Beta Laminations in Cartridge Brass", by R. L. Dowdell and others, *Transactions* American Society for Metals, V. 41, 1949, p. 985.)

Spectrographic analysis of the disks from both sources was made by Supplier Z, as shown in the table, without giving any clue to the difference between sound and defective cases. Spectrographic analyses by Triplett and Barton of Los Angeles also failed to detect harmful elements in troublesome amounts in several samples from defective cases.

Spectrographic Analysis of Disks

Elements*	Source of Brass	
	Supplier X	Supplier Z
Aluminum	0.00	0.01
Antimony	0.000	0.000
Arsenic	0.001±	0.003±
Bismuth	0.000	0.000
Boron	<0.01	<0.01
Cadmium	0.00	0.00
Calcium	0.00	0.00
Chromium	0.00	0.00
Cobalt	0.00	0.00
Iron	0.015	0.02
Lead	0.01	0.01
Lithium	<0.01	None
Magnesium	0.00	0.00
Manganese	0.000	0.00
Nickel	0.005	0.007
Phosphorus	0.00	0.00
Silicon	0.00	0.01
Silver	0.00	0.00 (trace)
Sodium	0.00	0.00
Tellurium	0.000	0.00
Tin	0.001	0.003

*Elements not detected in either sample: titanium, vanadium, mercury and barium.

All the samples examined had the characteristic grain size and constituents of alpha brass. No beta brass or inclusions were found, but samples cut from defective cases exhibited intercrystalline voids. See Fig. 4 to 6. While it is true that the gross fractures occurred substantially at the center of the head, corresponding to the center of the cast ingot and later of the disk, the intercrystalline voids were not confined to the center plane but were also found in adjacent regions of the head. It is to be noted that large amounts of cold work, as in the side walls of the cup, and subsequent stages of cold working to draw out the walls of the cases (with intermediate anneals at 1120° F.) prevented voids from opening, except in the head.

Some defective cases were returned to Supplier Z; it was reported to us that there was no obvious casting practice defect like a pipe or lamination. We confirm this; no trouble was encountered in drawing these cases, and no cracks were found above the radius. One of their metallurgists came to our plant and made numerous tests.

Thirty-two disks were run through the Reflectogage and indications for sound disks were obtained. Strips cut from three of these were fractured by reverse bending. These had silky fractures, indicating that these disks, as received, were perfectly sound.

Next, strips from two of these disks were annealed at 1150° F., stretched moderately in a tensile machine and re-annealed at 1150° F. Fracture tests of these pieces had an undesirable appearance—granular, rather than silky. These included strips which had been slowly cooled from the annealing temperature, as well as strips which had been quenched.

Strips from the same two disks were similarly annealed at 1000° F., stretched and re-annealed at 1150° F. Their fractures were also granular.

Strips from the third disk were annealed at 1000° F., cooled both in air and water, but were not stretched. These strips also had granular fractures, abnormal for cartridge brass. The tests showed

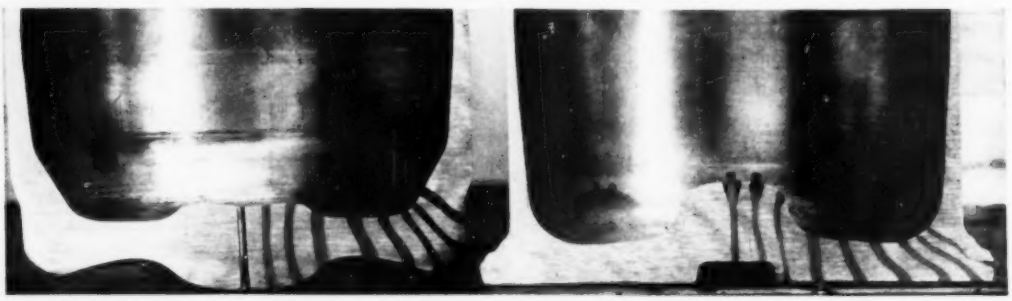


Fig. 2—No Horizontal Shear or Offsetting Occurs in the Preheading (Left) and Heading Operations, as Proved by Copper Wires Inserted in the Partly Made Case

that these sound disks developed granular fractures if they were annealed in the range 1000 to 1150° F., whether they were lightly cold worked or not.

Similar strips were cut from good disks of this lot and annealed at 1300° F. The fracture after this anneal was still silky. When such strips (annealed at 1300° F.) were stretched in a tensile machine and again annealed, some at 1000° F. and some at 1150° F., all showed normal silky fractures. This indicated a prior annealing of the disks at 1300° F. might cure the trouble.

Consequently, 300 disks were selected from stock, tested, and accepted by the Reflectogage as sound. They were annealed at 1300° F. in a continuous furnace (total time, 42 min.), pickled, and run into finished cases in exactly the same manner as all previous cases. They were then tested with the Reflectogage. Four cases were rejected; they were cut and minor cracks were found.

The hardness of the cases from this lot was the same as for the other cases made from disks as received. The grain size was only moderately larger—approximately 0.080 mm. We consider that the 1300° F. anneal changes the inherent structure of this brass so that the cases made from annealed disks are entirely satisfactory and will meet all required tests and specifications.

Some studies were then made to look into the hypothesis that grain size may have an influence.

The disks for this contract were ordered and produced to meet specification JAN-B-67, which calls for grain size 0.075 to 0.150 mm. for this gage. Supplier Z had modified the hot rolling process to produce this grain size. In the study of the grain size effect they shipped us 300 disks made according to their regular practices, with a grain size of 0.025 to 0.045 mm. We ran these through the Reflectogage, where they were accepted, and then into completed cases following our regular production process without incident. These finished cases passed the Reflectogage without any rejects. We conclude that these disks were free from the defect under discussion.

Subsequently about 85,000 additional disks for this contract were produced by hot rolling and with this same fine grain size (0.025 to 0.045 mm.). All of these disks processed satisfactorily and without incident into acceptable cases which had no rejects when tested by the Reflectogage.

It will be appreciated that the actual cause of the trouble noted at the outset is very obscure.* Supplier Z undertook an extensive investigation in their own plant seeking an adequate explanation for this completely abnormal occurrence. This took considerable time. Their findings are summarized as follows:

1. The material, as hot rolled and in the form of blanks, is perfectly normal in properties and differs from previous production for cartridge case blanks only in a slightly higher average grain size.

2. The intergranular weakness is developed in the hot rolled metal or the blanked disk by annealing at temperatures between about 575° F. and 1200° F. (In processing to cartridge cases, this corresponds to the anneal following the cupping operations.)

3. The degree of embrittlement depends on both the time and temperature. The most severely affected material is weakened by anneals over a considerable range of time and temperature from 750 to 1300° F. Less severely affected material shows embrittlement from 750 to 1000° F., with gradual healing at higher temperatures.

4. Annealing temperatures of 1300 to 1340° F. for 1 hr. total time eliminate the weakening effect in blanks or hot rolled material. Lesser temperatures for longer annealing periods—as, for instance, 6 hr. at 1150° F.—will restore normal ductility. The exact times and temperatures will vary with the severity of the embrittlement.

5. Microscopically, the weakening effect is related and apparently due to an intergranular material which is precipitated in the grain bound-

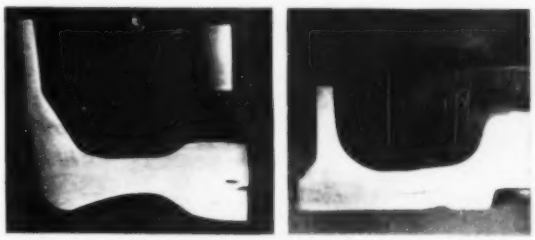


Fig. 3—A Cracked Prehead (Left) and a Defective Case Made by Conventional Two-Hit Heading Methods—not Preheaded

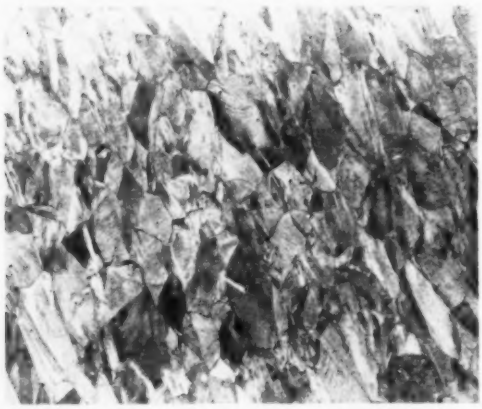
*Since the term "phantom laminations" was used by some metallurgists with long experience in cartridge case manufacture, the following citations to the literature may be apropos (although we are by no means implying that what we found at Norris Stamping and Mfg. Co. is identical with what the respective authors wrote about).

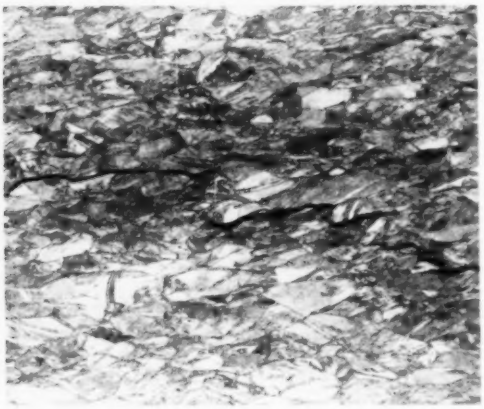
"Phantom Laminations in Brass", by D. R. Hull, H. F. Silliman and John R. Freeman, Jr., *Transactions* of the A.I.M.E., Institute of Metals Division, 1945, p. 203, 213.

"Phantom Laminations in Brass Disks Used for Artillery Cartridge Cases", Frankford Arsenal Technical Report T-212, October 1941.

"Phantom Laminations in 90-mm. M19 Brass Cases", Frankford Arsenal Technical Report T-354.

Frankford Arsenal Technical Report T-333.





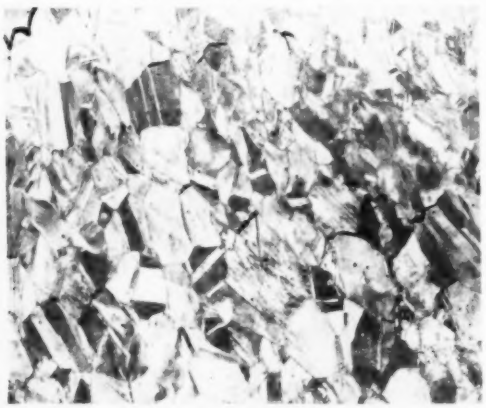


Fig. 4 (Top) Shows Case Head With Tiny Voids at Grain Boundaries; Fig. 5 and 6 Show Undoubted Intercrystalline Cracks.

aries by annealing after hot rolling. This intergranular material is coalesced by increasing the time and temperature of annealing, which gradually permits the return of normal ductility and tensile strength. It has not been possible to reproduce the effect (loss of ductility), or to reprecipitate the intergranular material once it has been coalesced or absorbed.

6. The weakening effect can be demonstrated qualitatively by reversed bend fracture tests and quantitatively by tensile and elongation tests.

7. The amount of intergranular weakening varies in material rolled in a commercially identical manner, but all material shows some weakening after annealing as indicated above. Maximum embrittlement varies in different bars, ranging from a 10 to a 40% decrease in ductility as measured by per cent elongation.

8. Material hot rolled to the same gage by more and lighter passes shows very little decrease in ductility, 5% or less, on annealing at any temperature. (It was on this basis that a sample lot was shipped to the Norris company and found 100% satisfactory.)

9. Hot rolled material — either badly weakened by annealing at 1020° F. for 1 hr., or as hot rolled — can be restored to or maintained at normal ductility by cold rolling as little as 30%. Higher reductions are desirable from the standpoint of uniformity of grain size. (The beneficial effects of cold work explain why the side walls of the cases are not affected by the embrittlement.)

10. Careful spectrographic and chemical analyses have not been able to detect any impurity or combination of impurities which might be expected to precipitate in the grain boundaries.

11. Several bars cast so as to minimize the pickup of gases during melting and casting were hot rolled in the same manner as the original material. Embrittlement in these bars was found to be about 5%.

12. Additional bars cast in such a way as to *increase* the likelihood of gas pickup were also processed in the same way and found to show embrittlement or loss of ductility from 25 to 75%.

Means of Prevention (or Cure)

It appears from the results of the experiments by Supplier Z that several means of correcting the trouble are available. The primary cause seems to be pickup of gas or nonmetallic impurities during casting — although the details of this are apparently not yet clear. It can be controlled by keeping the hot rolled grain size as fine as possible, consistent with necessary ductility, or by re-annealing the blanks above 1340° F. From a practical standpoint, care in casting and maintenance of fine grain in hot rolling are the best ways to control the difficulty.

Raising Industry's Stake in Atomic Energy

AN "Industrial Advisory Group" of eight well-known industrialists (James W. Parker, president of Detroit Edison Co., acted as chairman) has reported to the Atomic Energy Commission after a 14-month study of the problem of increasing the participation of American industry with the atomic energy project. A briefed summary of the 12,000-word report follows:

One of the serious obstacles in making our survey arose out of burdensome security regulations which constitute a formidable impediment to any attempt to understand the enterprise. This represents one of the most troublesome factors in any attempt to broaden industry's role in the program.

In certain respects industry already has an important part. Most of the work is carried on through contract with private firms and research institutions; the number of people engaged in this work exceeds 60,000. However, the only field of opportunity open to industry generally is in developments associated with radio-isotopes. This is a very promising field. But atomic energy undoubtedly holds many other promising opportunities for technological development, although as yet they cannot be clearly visualized.

Progress in atomic developments — for military as well as peaceful purposes — depends on getting answers to questions of extreme difficulty in the fields of physics, chemistry, geology, engineering and metallurgy. Success in solving comparable problems in other fields of technology has come about through energetic attack by many competing firms and individuals rather than by any select group. The Commission's contract system — though it includes some of the country's ablest industrial organizations — is not by itself a real substitute for this process.

We think that today the central difficulty in getting such a broad industrial attack is that industry has no way of determining whether important opportunities in fact exist in which to take part. It has been stated that industrial opportunities in atomic energy are potentially unlimited. But they are at present so shadowy that business men neither know where to look nor what to look for.

Much information has already been published by the Commission, but most of it is not in a form that is useful to industry. In addition, a vast amount of nonsecret information of potential value to industry is buried in the files of the Commission. Other information is still classed as "secret", but the continuance of secrecy is of doubtful value.

We observed, for example, valuable new metallurgical techniques, new chemical treatments to protect against corrosion, new instrumentation, and useful technical knowledge of many kinds. This information is only incidentally related to atomic energy, yet it is still largely unknown.

For reasons which are not at all clear, much of this knowledge is still buried in the files. It should be published at the earliest possible date. The cost of secrecy is high. This is one of the many instances in which we have thought its value doubtful.

There is a second class of knowledge which must be made available in order to complement the first — namely, information about the structure of the Commission, its administrative policies and its procedures. The better industry is informed about these matters, the better it will be able to deal with the Commission with assurance and understanding.

In order that published information about the Commission will be complemented by concrete first-hand personal contact, the Commission should develop a broad program for clearance of engineers, technologists, and executives in the interested industries. These include chemical, petroleum, power, heat transfer equipment, metallurgical, and instrument industries. Qualified men in these industries should be given an opportunity to keep in touch with atomic energy in the same manner as they keep informed of other technological developments.

Even more important is the development of a parallel program to bring outside executives in close touch with developments. In all of the industries likely to be interested there are several hundred men in top executive positions who have an over-all responsibility for technological matters in their companies. The Commission should develop a program to give such men first-hand, continuing experience with the subject.

One of the best devices would be a system of industrial advisory committees. By virtue of their membership on such committees, the men would more readily provide a channel of communication between the Commission and industry. In the same way, committee members would be available to assist the Commission in the difficult problem of recruiting key personnel. They would also frequently be able to assist the Commission in developing its preliminary approach to specific problems affecting industry. They would be of special assistance to the Commission in setting up temporary and special advisory committees to deal with specific problems.

A principal value of the advisory committee idea lies in the education of industry. In order to perform their assigned task, no matter how special it might be, committee members would acquire a general background in the broad subject of atomic energy. The increased understanding would flow from the committee member through his own company and more generally into industry. Perhaps most important, the advisory committee program will lead to many ideas, now impossible to anticipate, for further expanding industrial participation in atomic energy.

Finally, the Commission should give particular attention to acquainting industry with the specific measures it is now taking to improve and strengthen its contract system of operation.

Presentation of verbatim extracts from important contemporary documents concerning atomic energy does not imply that the Editor agrees with the opinions quoted, nor that they are expressions of A.S.M. policy.

DETECTION OF FERRITE BY ITS MAGNETISM

By T. V. Simpkinson* and M. J. Lavigne
Bureau of Mines
Ottawa, Canada

BY MICROSCOPIC examination alone, it is often difficult to identify small amounts of ferrite in austenitic stainless steels — particularly in welds, due to the fineness of the microstructure and because dendritic segregation, in itself, often produces etching effects which complicate the interpretation.

However, the use of ferromagnetism measurements in conjunction with micro-examination offers a good means of predicting or confirming the presence of ferrite. Fully austenitic stainless steel is not ferromagnetic; sigma phase and carbides in stainless steels are not ferromagnetic; therefore any ferromagnetism detected must be due to the presence of ferrite. Phase changes involving ferrite, brought about by heat treatment, may thus be followed by measuring the ferromagnetism of respective samples.

The Aminco-Brenner Magne-Gage, ordinarily used to measure the thickness of coatings on magnetic materials, is a very useful instrument for measuring the relative ferromagnetism of slightly magnetic specimens. We have found it to be sensitive, and readings can be taken very quickly and simply. Dial readings, obtained by its use, have been correlated with the micro-

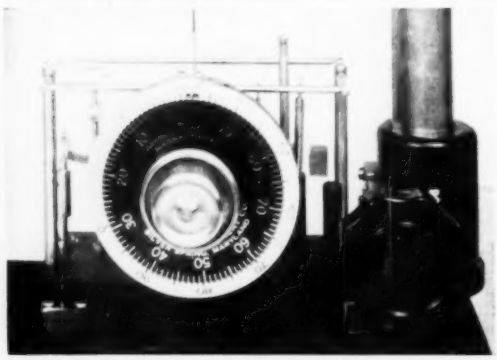


Fig. 1 — Dials at Front of Instrument When Lever Arm Is in Balance

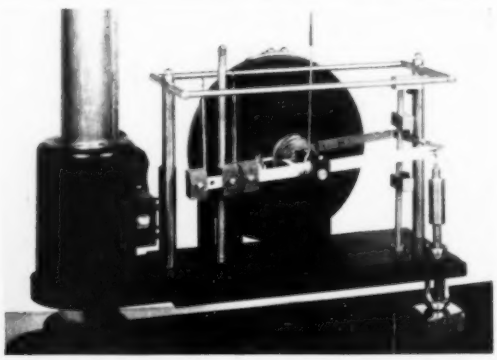


Fig. 2 — Back View; Magnet at Extreme Right, and Right Foot Resting on Cubical Specimen

structures observed for various stainless steel welds and plate material. The gage was calibrated with a series of compacts of iron powder and bakelite.

The Magne-Gage consists essentially of a small permanent magnet, 0.08 in. diameter with hemispherical contact end, suspended from a horizontal lever arm. The lever arm is actuated by a beryllium-copper spiral spring which is coiled by turning a knurled knob clockwise. A graduated dial indicates the amount of rotation.

Figure 1 is a front view of the gage with its protecting cover removed. The magnet has been lowered on the specimen, and the dial is set at zero position, as explained below. Three magnets, each of different strength, are provided; the strongest was used in this work.

Only the outer of the two circular scales is used. The zero, or starting position, is set thus:

The dial is turned counterclockwise until rotation is prevented by a stop. In this position the spring is uncoiled as far as possible and the outer dial reading will be about 60. The dial is now turned clockwise, with magnet No. 3 in place but not in contact with a magnetic specimen, until the lever arm (shown in the back view, Fig. 2) is just in balance. As shown in Fig. 1, the actual dial reading is then 32, which is, therefore, the "zero" position for the purpose with which this paper deals. From this point, the dial may be turned clockwise through 138 scale divisions before a second stop is reached at the fully coiled position of the spring. The range of readings with the strong magnet No. 3 is, therefore, 0 to 138.

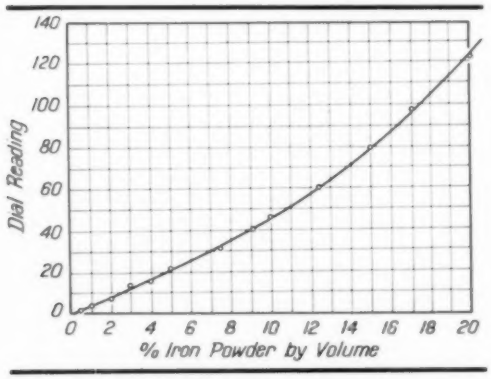


Fig. 3 — Calibration Curve for Iron in Iron-Bakelite Compacts

Many of the obscure troubles, now and then experienced by stainless steels of the 18-8 family, are ascribed to changes in microstructure — such as development of ferrite from the desired austenite structure, and its subsequent change into brittle sigma phase. Detection of ferrite in these duplex structures is difficult and likely to be erroneous if the microscope is used alone. As the authors show, the measurement of residual magnetism is a sensitive detector of ferrite, although when sigma phase co-exists the magnetic and microscopic estimate of amounts present may differ considerably.

A reading is taken as follows: With the specimen in position (right, in Fig. 2) and the dial set at "zero", the coil spring is gradually tightened until the magnet is suddenly raised from the specimen. In this paper, the magnetism readings given are the actual number of scale divisions traversed before the magnet is raised.

Calibration

As a means of correlating Magne-Gage readings with the actual amount of ferrite present in a specimen, compacts of electrolytic iron powder and bakelite were made which contained percentages of iron powder, by volume, within the range of 0.5 to 20.0%. The calibration curve is shown in Fig. 3.

The average reading for the compact containing 20% iron was 123. As the upper limit of the scale is a reading of 138, magnet No. 3 can be used only for specimens containing no more than about 21% of ferrite. For specimens with a greater amount of ferrite the weaker magnets provided with the equipment must be used.

To form the compacts the bakelite was screened through 100 mesh. For those with 4%

*Mr. Simpkinson is head of ferrous metals laboratory in the physical metallurgy research laboratories, division of mineral dressing and metallurgy of the Canadian Bureau of Mines; Mr. Lavigne is resident physical metallurgist of the Bureau of Mines at the atomic energy project of the National Research Council at Chalk River, Ontario. This paper is published by permission of the director of the mines, forests and scientific services branch of the Department of Mines and Resources.

iron and less, the iron powder was screened through 325 mesh. For the higher percentages of iron, −200-mesh powder was used, except some duplicates made with −325-mesh iron so that results with the two powder sizes could be compared. (For the higher iron contents, at least, there is apparently no advantage in having the iron finer than 200 mesh.)

Before taking Magne-Gage readings, $\frac{1}{16}$ in. was ground from each face of the compacts on an abrasive belt, using a medium grit. There was no evidence that this grinding tore out any iron powder particles. The volume of iron powder at the surface of the green compacts was low; therefore, after grinding the average reading was higher, and the readings were more uniform.

Because of the imperfect distribution of iron grains throughout the compacts due to incomplete mixing, and the inability of the small magnet to magnetize ferrite in more than a limited region adjacent to it, a variation in readings from point to point must be expected. Thirteen readings were taken at various points on each side of each compact. Some varied from the average by about 10%, but the averages all fell very close to the smooth curve shown in Fig. 3.

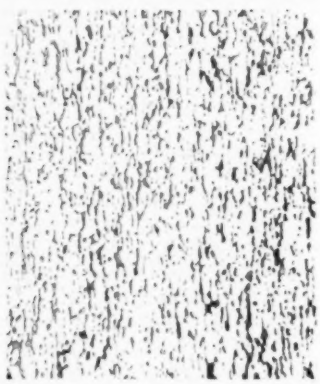


Fig. 4 and 5 — Two Samples of Type 316 Stainless Steel (18-12-3); Magnified 80 Diameters, Etched in Modified Murakami's Reagent, Boiling. Magne-Gage readings 105 and 1 respectively, corresponding to 18 and 0.5% ferrite

Estimation of Ferrite

Figures 4 and 5 illustrate the ferrite-austenite structure of specimens of A.I.S.I. Type 316 steel containing, respectively, a large and a small percentage of ferrite. The Magne-Gage readings were 105 and 1, respectively, corresponding to 18 and 0.5% of ferrite.

The percentage of ferrite in the field of Fig. 4 was determined by the technique of point counting.* The resultant figure was 21.1%, which is in fair agreement, and indicates that the permeability of ferrite in Type 316 stainless steel, water quenched from a high temperature, does not differ greatly from that of the iron powder used to make up the iron-bakelite compacts.

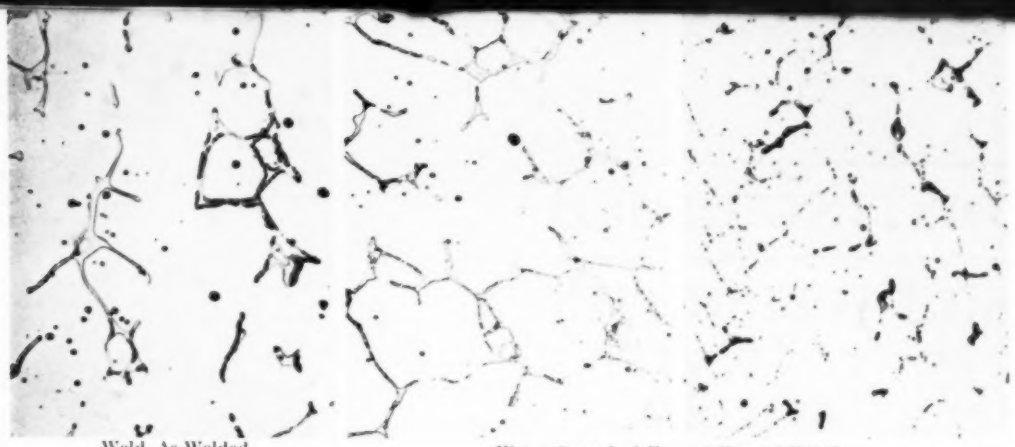
Transformation of Ferrite

Figures 6 to 8 show the structure of a weld made with Type 316 welding rod. Figure 6 represents the "as welded" condition; its structure consists of ferrite pools in an austenitic matrix, with carbide precipitated at the interfaces. Magne-Gage readings as high as 40 were obtained at some points in the weld.

A section from this weld was heated at 1600° F. for 4 hr. and then water quenched. The structure, developed by the same etching technique, is illustrated by Fig. 7, and it might be judged to be quite similar to the view as welded. However, when tested on the Magne-Gage, zero readings were obtained; thus, at the most, only a fraction of 1% of ferrite can be present. After etching electrolytically in 10% oxalic acid, which darkens sigma phase, the structure shown in Fig. 8 was revealed. The 4-hr. treatment at 1600° F. has apparently caused the ferrite to change into nonmagnetic sigma phase, and probably also in part to austenite.

The progress of ferrite breakdown in A.I.S.I. Type 316 steel, with time, at 1600° F., is followed in Fig. 9, 10, and 11. Figure 9 illustrates the ferrite-austenite structure of a specimen that had been water quenched after holding for 2 hr. at 2200° F. Magne-Gage readings on this sample

*In point counting, a finely lined rectangular grid is attached over the photomicrograph, or else is printed on it by double exposure. The percentage, by volume, of a given constituent in the microstructure is obtained as follows: First, the number of line intersections that are located within this phase are counted; then the percentage that this number is of the total number of line intersections in the whole field is a true percentage of the constituent in that particular field.



Weld, As-Welded

Water Quenched From 4 Hr. at 1600° F.

Fig. 6 to 8 — As Welded Structure (Left) Containing 9% Ferrite Appears Unchanged (Center) After High Temperature Treatment, but Magne-Gage Reports Less Than 1% Ferrite. This is verified by oxalic acid etch, at right, which darkens sigma phase. 800 ×

were from 101 to 105. A piece of this material, subsequently held 20 min. at 1600° F., gave readings of 37 to 40. Its microstructure is shown in Fig. 10. On a specimen that had been heated 4 hr., readings were 13 to 14; its microstructure is illustrated by Fig. 11.

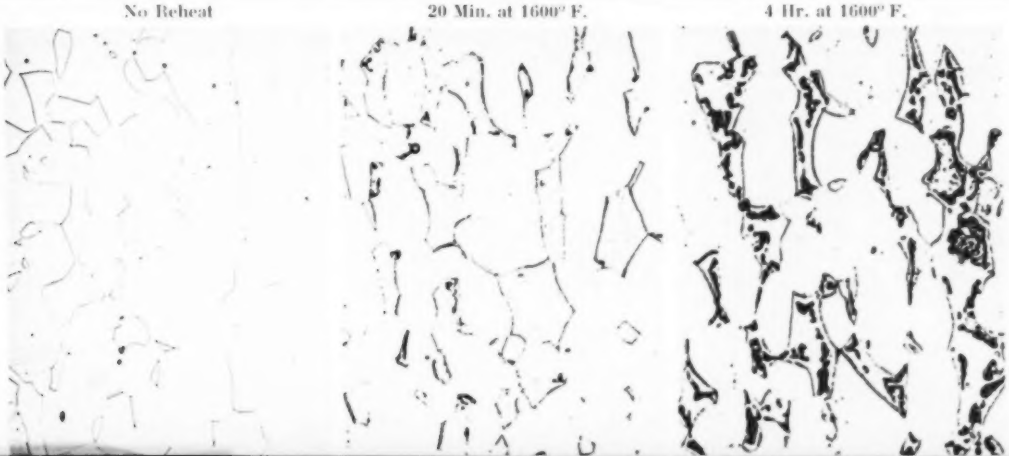
Using the curve of Fig. 3, the Magne-Gage readings indicate the percentage of ferrite to be 18% in the as-quenched sample. Point counting a field that was judged to be an average of this specimen (at 100 diameters magnification) gave 19.5% ferrite, which is in good agreement.

For the sample heated 20 min. at 1600° F., the Magne-Gage readings correspond to 8.7% ferrite, whereas point counting the field of Fig. 10 (at 500 diameters) gave 12% ferrite. The same result was obtained when an average field of this specimen was counted at 300 diameters magnification. The estimates obtained by the two methods are here in poor agreement, but after only 20 min. reheating, sigma phase formation is at an early stage and it has often been observed that the presence of this phase is reflected in changes in mechanical and magnetic properties before it can be detected microscopically.†

For the specimen reheated 4 hr. at 1600° F., the result of point counting two fields at 300 diameters was 2% ferrite in each case, whereas the Magne-Gage gives 3.3%. In this specimen, a relatively large amount of the chromium-rich sigma phase has formed, and it is, therefore, possible that depletion of chromium in the remaining ferrite has increased its permeability.

†See Smith and Bowen's paper entitled "The Occurrence and Some Effects of Sigma Phase in a Molybdenum-Bearing Chromium-Nickel Austenitic Steel", *Journal* of the Iron and Steel Institute, March 1948.

Fig. 9 to 11 — Transformation of Ferrite in Type 316 Stainless Steel During Reheating at 1600° F. Electrolytic etch in 10% oxalic acid; 400 ×. Magne-Gage readings are 101 105, 37 40 and 13 14, corresponding to about 18, 9 and 3% ferrite respectively



No Reheat

20 Min. at 1600° F.

4 Hr. at 1600° F.

DISTINGUISHED METALLURGISTS

SEVENTY-FIVE American and Canadian engineers, metallurgists, business men (some 50 different titles are in the roster) were honored at the last ASM Convention for their unusual and meritorious contributions to progress in alloy steel. In the following pages are brief biographies of eight of them. *Metal Progress* will continue the pleasant task of honoring these leaders in the metallurgical industry until the list is completed.

J. M. Schlendorf

Vice-President in Charge of Sales
Republic Steel Corp.
Cleveland

Citation "for pioneering and continuing efforts to promote the use of alloy steels throughout American industry"

A YOUNG MAN (he was 31 years old) moved from a job as assistant purchasing agent for Willys-Overland Co. in Toledo in 1917 to another as vice-president in charge of sales for Central Steel Co. in Massillon, Ohio. This was an important title, but the company was a small producer of alloy steels in electric furnaces, a high-priced specialty that had to be *sold* to reluctant buyers, once World War I was over. This young man remained with that company and its successors, assuming greater and greater responsibilities with the years, and exerting pronounced influence on the increase of electric furnace production in America from less than 350,000 tons in 1917 to more than $3^3/_4$ million tons in 1947.

Steel users, in the 1915-1925 decade, knew carbon steels but few of them knew much about alloys. Perseverant JACK SCHLENDORF rang doorbells and called on hundreds of potential customers in person. He had to convince them that through the use of more expensive electric furnace alloy steel instead of carbon steel they could reduce both size and weight of steel parts, make an article that was worth more money and, more important, know in advance what was going to happen.

He was one of the first to put a trained metallurgist into the sales department. He took this step when he found that successful use of alloy steels required more science and less art, and that metallurgy was needed as a sales tool. Hence it is that scores of steel salesmen and sales executives look back on their training under JACK SCHLENDORF as the first step in a successful career.

T. D. Sedwick

Engineer of Tests
Chicago, Rock Island & Pacific R.R. Co.
Chicago

Citation "for pioneering and constructive work in applying alloy steels to locomotive forgings"

PRIOR to joining the Rock Island in 1903 (as chemist, later inspector of materials, chief chemist and metallurgist, now engineer of tests), T. D. SEDWICK was in charge of foundries for Stover Mfg. Co. of Freeport, Ill. A Missourian by birth, he graduated with arts and science degrees from University of Arkansas, and later took special courses in engineering and metallurgy. His sound judgment in all matters relating to railroad equipment for safe and reliable operation is evidenced by the fact that, from 1938 to 1948, he was chairman of the specifications committee of the Assoc. of American Railroads.

His most vivid personal recollection of incidents concerning his citation "was the difficulties connected with the manufacture and heat treatment of the large forgings required for locomotives to develop the potential mechanical properties of the alloy steels. Proof testing was largely by shock blows, and numerous forgings would pass such tests, but fail later in service, the fracture being longitudinal rather than transverse. Increased wear resistance was expected through the use of certain alloys, but due to improper heat treatment, some such parts wore

faster than ordinary plain carbon steel! A persistent program of development, however, gave us sound billets, forgings whose flow lines were properly disposed, and correct analyses and heat treatments — all together resulting in greatly improved service from the alloy steel forgings, and at the same time making it practical and safe to use lighter sections for the same or even heavier loadings."

William John MacKenzie

Manager of Alloy Steel Sales
Youngstown Sheet & Tube Co.
Chicago

Citation "for promoting the use of alloy steels throughout American industry"

A Harvard graduate, Bill MacKenzie returned to his home town of Canton, Ohio, and got a job at United Steel in the fall of 1913. It is undoubtedly indicative of his success in "promoting the use of alloy steels" that no less than 20 of his 35 years in the business have been in the mills of United, Interstate and Republic. In approaching customers, he knew of a certainty what he was talking about. How far this body of real information has progressed since the early days is recalled by him in these words:

"No incident stands out more clearly than the one at the old United Steel in Canton during World War I when we were making, for the first time in this country, nickel-chromium-moly steel in the electric furnace. Ford Motor Co. had ordered a real tonnage of it for Liberty motor crankshafts and connecting rods. The heats were watched by several leading metallurgists. The first six looked perfect in the furnace, the taps were regular, the chemistry was within the ordered limits, the heats rolled without trouble, but all fell down on a transverse test; all showed peculiar fractures. One prominent metallurgist called the bright spots in the fractures 'seeds', another 'snow flakes', while still another had no better name than 'those things'!

"It was winter — and climate is an essential factor in steelmaking, as all good steel-men know. Heat No. 7 arrived along with a thaw, but before it was rolled a blizzard arrived. Now, this heat looked fine in every way. It was rolled and dumped on the ground where all six previous heats had been dumped. However, we, the employees, had put up a screen of galvanized sheets to protect ourselves from the cold because a large door was frozen and wouldn't close. An extra heavy gust of wind blew the sheets over on the steel. This heat No. 7 passed all tests, including the transverse test! Someone finally came up with the idea that this Ni-Cr-Mo steel should be cooled slowly, so for heat No. 8 we dug a pit, buried the hot steel, and it passed all the tests. So did the rest of the heats. We had the cure long before the disease was diagnosed.

"Indeed we have come a long way, metallurgically, from the days when we had an air hardening analysis but didn't know it!"

John Mitchell

Assistant to Manager of Sales,
Alloy Division
Carnegie-Illinois Steel Corp.
Pittsburgh

Citation "for leadership in the development of National Emergency alloy steels"

Mitchell is a Hoosier who went to work as a heat treater at the ripe age of 17 and during the next eight years grew to be an expert on gears and axles. Seven years with Republic as service contact metallurgist was followed (1936 to date) by various appointments concerning alloys on the Steel Corporation's staff. During the war, he was a member of no less than 11 committees having to do with the constructional alloy steels. Their activities funneled through the technical committee on alloy steels of the American Iron & Steel Institute, whose recommendations were usually accepted and enforced by the War Production Board. Early in 1941 it became apparent that supplies of the "critical" alloys nickel and chromium would be insufficient for the demand of the standard S.A.E. steels, and more complex steels relying heavily upon the alloy content of circulating scrap must be substituted — and quickly, without resort to time-consuming tests. General information on the effect of each of the principal alloys on steel, and specific information gained by hardenability tests on trial heats, enabled John Mitchell's group to devise these National Emergency Steels, "whose formulation was one of the outstanding metallurgical accomplishments of World War II", in the words of Louis Jordan, executive secretary of the War Metallurgy Committee. Today some of these steels survive as A.I.S.I. standard "H" steels, produced to guaranteed hardenability limits.

Robert R. Abbott

Director of Metallurgy
White Motor Co.
Cleveland

Citation: "A pioneering authority on the intelligent use of alloy steel, who influenced practices in many consuming industries"

CASE SCHOOL OF APPLIED SCIENCE (now Case Institute of Technology) graduated ROBERT R. ABBOTT in 1902, and he taught chemistry and metallurgy there until 1910, when Peerless Motor Car Co. of Cleveland hired him as metallurgical engineer. So ABBOTT is a thorough Clevelander, having been with the Peerless and White Motor companies continuously since that time.

When he went with Peerless in 1910 all important forgings and the cylinder blocks for that automobile were bought from French concerns. It was thought that satisfactory materials could not be made in America. Abbott at once recognized the fallacy of this assumption, and for four years intensively studied bars of every alloy steel then made in Europe and America. He was able to connect their physical and chemical properties with simple mathematical formulas, wherewith he devised new analyses made in the U.S.A., with appropriate heat treatments.

His influence did not stop there. WALTER GROTHE, retired chief metallurgist of Caterpillar Tractor Co., has this to say:

"In the development of tractor design we found that automotive experience was seldom applicable. So we sought information throughout the Midwest and East, but our prize discovery was ROBERT ABBOTT. My approach to him — about 1920 — resulted mainly from his name having been repeatedly mentioned as the pioneering authority on intelligent use of alloy steel. Whenever requested, which was repeatedly during at least five years, he gave me clear conceptions of fundamental principles, technical facts and their application, along with comparatively simple, direct methods of investigation or testing. Much of that technique became a permanent part of Caterpillar practice.

"A notable trait was that he had boldly rejected or avoided the rather restricted, prejudiced or distorted metallurgical data offered in those years, especially on alloy steel physicals, which tended to mislead us novices."

Franklin Institute awarded him the coveted Edward Longstreth medal for his work on modern steels. Harvard University, as well as Case Institute, has also awarded the degree of Metallurgical Engineer to ROBERT R. ABBOTT. In this they have only followed the accolade of men without number in the metals industry.

J. B. Johnson

Chief, Materials Laboratory
Engineering Division
Wright-Patterson Air Force Base
Dayton, Ohio

Citation "for establishing and maintaining quality standards in the aircraft and air engine industries"

JOHN BURLIN JOHNSON was born in Olean, N. Y., and graduated in mechanical engineering from Cornell University. He was very early attracted to the then infant aircraft industry and for the past 30 years has served as materials engineer and director of research and development on materials for the U. S. Air Force — the principal customer of the American aviation industry. Well-known and highly respected, one might well say: "His knowledge about aircraft materials is encyclopedic; his influence immense."

In 30 years, methods of inspection have grown so searching that "aircraft quality" represents the ultimate an' alloy steelmaker can produce. The very beginning of these complicated special requirements is recalled thus by Johnson:

"The first problems of quality control were confined to selecting the best of the commercial materials by sampling. This type of inspection was more satisfactory for such materials as wood, fabric and the products of the chemical industry, than for metal. Each piece must carry its full burden and therefore must approach commercial perfection. This involves metallurgical control throughout the producer's and the fabricator's plant. An early step in the search for hidden defects in alloy steel was taken during a visit with the late Alfred de Forest in his small laboratory in the basement of the American Chain Co. and obtaining his assistance in the construction of a magnetic apparatus suitable for determining the presence of cracks and other defects. The first magnets were coiled by hand and used by Dr. de Forest at Wright-Patterson Air Force Base on several airplane and engine parts. The results were so satisfactory that improved equipment was built and the eventual 'Magnaflux' process became an essential adjunct to quality control in the mill and shop, and for parts inspection in the repair bases."

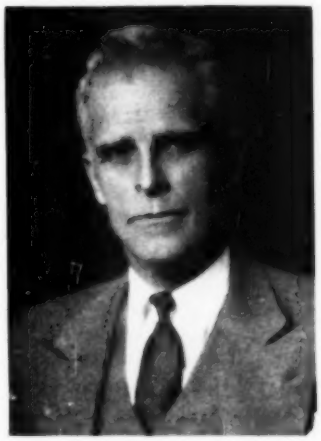
Robert W. Schlumpf

Chief Metallurgist
Hughes Tool Co.
Houston, Texas

Citation "for utilization of alloy steel in oil well drilling equipment"

BORN in Sewickley, Pa., and a graduate (B.S. in Met. Eng.) from Carnegie Institute of Technology in 1921, Bon SCHLUMPF spent the first three years of his post-graduate training in the not unknown scheme of holding down jobs as geographically diverse as Ohio and Oregon, but all fitting him for employment by Hughes Tool in 1924 as melter in the electric steel foundry. Here he lived through a revealing experience of great importance to his present work — he witnessed a transition from the old established tenet of acid steel foundry "experts" that the bath should be melted with minimum oxidation and aluminum avoided, to an entirely unorthodox improvement, namely, a vigorous meltdown oxidation reaction, and liberal use of the formerly "poisonous" aluminum in the ladle. This was found to produce the best steel for sand castings.

How that revolution in steel foundry practice ties in with his later work warranting the citation can be told in his own words: "The application of alloy steels to oil well drilling equipment has in general been a problem of meeting the ever-increasing brutality of service imposed during the past 20 years. Yesterday's unorthodox materials and processes have become today's standards. Conventional evaluations of the mechanical properties of materials have not been very helpful in meeting service demands that are unmatched (as far as I know) in any other industry. The future, as wells are drilled to new record depths, needs close coordination of effort of the designer, the metallurgist and the user for obtaining the ultimate of service from well drilling equipment."



Alan Kissock

Consulting Mining Engineer
and Metallurgist
New York City

Citation "for devising correct steelmaking processes, especially for the molybdenum alloys"

RECOLLECTIONS of incidents during the work for which the citation was made are best recounted in KISSOCK's own words:

"About 1913 an investigative Arizona cowpuncher came up with some pretty yellow crystals. Although identified as a molybdenum mineral this did not mean a great deal, for (excepting some German metallurgists) few knew much about the metal. However, the yellow crystals became sufficiently interesting to me to build an 'adobe' smelter in Tucson to convert the ore into lead bullion and sodium molybdate slag. This process was later improved by leaching the wulfenite to produce a high grade lead residue and calcium molybdate.

"During World War I it was discovered that effective use of the metal molybdenum was being made by the Germans, so the Naval Gun Factory in Washington decided to make some electric heats of 1% molybdenum steel. No ferromolybdenum was immediately available and the late PAUL E. MCKINNEY (then in charge) agreed and was the first to introduce moly into steel via calcium molybdate (1917). These heats were successful and were shortly followed by others at the Naval Ordnance Plant in South Charleston (C. E. MARGERUM, metallurgist).

"By this time it was admitted that reduction of calcium molybdate in the electric furnace was not too surprising — but the openhearth presented quite a different problem. Nickel-moly ballistic tank plate was becoming important, and I was sent by the War Industries Board to Carbon Steel Co. in Pittsburgh, where both electric and openhearth heats were made under direction of A. H. SONNENHALTER and GEORGE LOEFFLER.

"Thanks to the Climax Molybdenum Co., and the late B. F. PHILLIPSON, its then president, C. HAROLD WILLS of Ford Motor Co., and other enthusiasts, the virtues of 'moly steels' and of calcium molybdate were slowly being recognized. In May, 1919, H. R. JONES of United Alloy Steels in Canton agreed, against the misgivings of his staff, to make two 100-ton basic openhearth heats. This became quite an event, with an array of talent on hand. Until this time ferromolybdenum was used like ferrovanadium and preheated for ladle addition. In these tests calcium molybdate was added as the 'lime began to come up'. If we 'ored down' we were 'goners for sure' (as PETE CAMERON expressed it) and because decision to do so was somewhat delayed the molybdate was in the furnace for 14 hr.! Under the strongly oxidizing conditions of openhearth melting it was considered fantastic to expect reduction of a small percentage of molybdenum from the furnace slag. We had aimed for 35 points and, at Benders that evening, bets among the group ranged from zero to an optimistic five points in the ingot. Final analysis gave 33 points!"

AN ADVENTURE IN METALLISM

By I. R. Ontowit
Hard Knox University

OUR WORK in the study of metallism at Hard Knox University is primarily concerned with the practical application of principles. We try to encourage our students to be practical in their thinking. Sometimes this policy has been a source of embarrassment to us on the faculty when we teach certain theories, but we have managed to carry on. I presume we are no more successful in this respect than any other similar establishment. We console ourselves with the belief that efforts to advance the frontiers of knowledge are never ending but quite often the importance of a simple idea becomes great when the practical significance of that idea becomes recognized. And sometimes recognition is gained only after strenuous effort.

Ever since the curriculum in metallism was established we have been trying to comprehend the connection between the performance of metals in certain laboratory tests and their performance under various service conditions. Correct interpretation of these relationships would undoubtedly enable the engineer to utilize test data more efficiently in the selection of metals. This is not simple either in concept or usability; neither is its complexity to be unexpected.

In the laboratory relatively small specimens are tested to ultimate fracture. Certain measurements are made of load applied during the test and the changes in dimensions of the specimen. These data apply to the performance of the metal in the test specimen throughout both the elastic and the plastic range of its resistance to fracture. However, in the actual service structure we design for the metal to perform in the elastic range *only*. Any appreciable plastic behavior of the structure usually connotes failure, even though the metal has not begun to rupture. Also the stress-strain pattern in the test specimen is seldom if ever the same as that in the metal of the structure under service loading.

These considerations cause us on the staff at Hard Knox to wonder how dependably we can predict service performance from test data. More particularly we have been concerned with the use of Charpy notched-bar impact bend test data and the significance of what has been called "transition temperature" as determined by that test. "To what extent does this test indicate serviceability?" This is the very pertinent question recently raised in one of my classes. At the time I had to be honest and say I did not know.

A little later, some light was shed upon this question by a learned faculty colleague who is in charge of the department of mechanism, Prof. Y. B. Dumbkoff. We were seated in the faculty lounge of the Student Union, for a few moments of relaxation after a strenuous afternoon. There were several faculty members in our group briskly discussing affairs of the day, to which I was idly listening without comment, when my colleague Yukan suddenly remarked to me, "Izzy, you seem so preoccupied. What is on your mind?"

To tell the truth I had not been listening to the general conversation, and I apologized to him for my preoccupation.

"Never mind that," he said smiling, "I'd like to know just what you were concentrating on so earnestly. You seemed to be way off in space somewhere. What is this problem of yours? I'd like to have a try at it too."

Engineers generally get pretty rusty with their mathematics, except for often-used formulas solved by slide rule. Consequently they shy away from strange equations, or refer them to younger associates. Nevertheless, now and then something comes along that needs attention. Here is something serious about brittle fracture treated in a semi-serious way.

For a moment or two I wondered whether he was trying to be funny, and then I replied, "It comes from the laboratory work I was supervising this afternoon — Charpy testing. I was glad none of the students asked me what we were going to do with the foot-pounds it takes to break the nicely machined specimens. I haven't the faintest idea what I could say."

Dumbkoff grinned. "You are a practical man unsuccessfully groping around in space, looking for a tangible thread of evidence, when this thread is an intangible one, one which must be sought in the impractical field of theoretical analysis. That's where we mathematicians come in. But tell me — from a practical standpoint, what does the Charpy test show?"

"Well," I began slowly, as I collected my thoughts, "I consider that the Charpy test indicates whether a metal will fracture in a ductile or brittle manner under the stress-strain conditions existing in the test bar as the hammer hits it. However, these conditions are certainly seldom met in service."

Yukan was silent for a moment and then he said, "Izzy, your reference to the manner of fracturing of the test bar is a significant point. It gives me an idea which might be of use."

"But," I asked, "how can one use a *type* of fracture to predict performance in a structure in service? It's the *capacity* to carry load which counts in design. The two don't add up."

"Wait a minute — not so fast! I think they do. The designer needs a metal which will not only carry the loads for which the structure is intended, but also one which will not break in a brittle manner under loads for which the structure is *not* intended — either accidentally, or because the designer did not foresee them. His most uncertain problem is calculating or estimating the probability and amount of overstress and making suitable allowances. This involves safety factors which of course are rather crude approximations. You see, Izzy, a metal does not break in a completely brittle manner unless the yield stress or flow stress equals the fracture strength of the metal. Then, if you practical men would look at the fracture you would say it was completely 'crystalline', but what you would mean is that there was no plastic flow of the metal prior to the break. You have already in the Charpy test (perhaps without knowing it) provided two of the three conditions necessary for fracture without plastic flow — that is to say, rapid application of stress when the swinging hammer hits the specimen, plus what we theoreticians call 'restraint'. By that I mean that the metal which gets the brunt of the load, at the root of the notch, is held tightly by its surroundings, by the very design of the test piece itself, and *prevented* from moving in such a way as to enable it to absorb its punishment better. That's a crude way to rationalize the mechanism of plastic flow; anyway, what I am reminding you of is that your Charpy test deliberately fosters the crystalline or nonplastic fracture by rapid strain rate and by restraint of the metal. A third factor that acts in the same way, if you remember, is refrigeration."

"That's all right," I had to agree, "but what does all that have to do with service performance? We make the test and determine the type of fracture as well as the energy required to break the bar. Where do we go from there?"

Yukan replied, "Well, Izzy, you could use it as a 'go' and 'no go' proposition. Already a minimum energy value at some specific temperature is sometimes selected for a particular application but not much attention is given to the type of fracture of the test bar."

I interrupted, "Yes, I have used that system, but even when there is considerable service experience there is still a certain amount of guesswork involved. Also I do not know of any method for evaluating degree of restraint or strain rate pertaining in the metal of the structure under service loading."

"Maybe we don't need to do that just yet," said my friend Dumbkoff. "Maybe you've heard of the flow-fracture stress theory of Zener and Hollomon, and maybe since there was an exponential formula connected with it, you (like all the metallurgical experts I know, except one) have shied away from it. I've thought about it a lot, though, and while this theory may not be perfection, it does enable one to explain certain metal performances. According to these theorists the yield stress or flow stress varies with strain rate and absolute temperature in this way"; and here he scribbled on the back of an envelope the following equation:

$$\text{Flow stress} = (\Sigma)\, e^{x \div T}$$

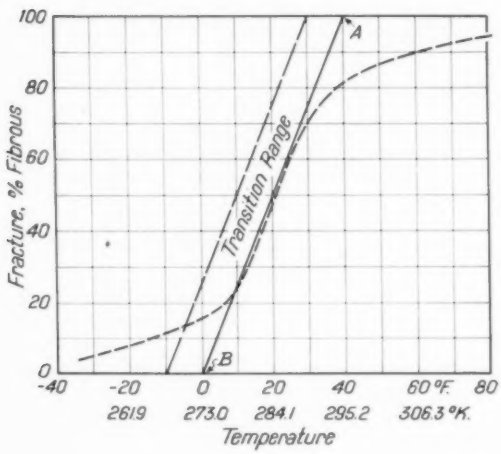
Where (Σ) = Rate of strain
x = A material constant
T = Absolute temperature (°C. + 273)
e = Base of the natural logarithms

"Now for the time being let's concentrate on the idea that the flow stress is the most important thing. If it equals the fracture stress we'll have a completely brittle fracture. In service we want to avoid this, by all means. We must keep the flow stress below the fracture stress, and then the material will flow — deform plastically, you would say — before it breaks. Now, if you follow me, it is apparent that the principal thing is to try to determine the conditions for a completely brittle fracture, and when we know them we can avoid them in service. Do you follow?"

"Yes, in a confused sort of way," I said. "From your argument I gather that we should try to determine a limit for brittle fracture so that we can always keep the service conditions above that limit to prevent such fracture."

"That's right! And here's where the Charpy test that you're worrying about comes in, for it's elementary that most metals change from a ductile fracture to a brittle fracture as they are tested at a lower and lower temperature. You know — the 'transition temperature'."

And Yukan took his pencil again and sketched the diagram I have copied, talking as he went:



"This will do to explain the idea: I have made the changes in direction quite sharp, although curves drawn from impact tests giving foot-pounds of energy absorbed approximate the dashed line. Where would you locate the transition temperature, Izzy?"

I studied the sketch for a moment and, indicating Point A, I remarked, "To my mind this point indicates the temperature where evidence of brittleness begins to appear in the fractured surface. However, the fracture is not completely brittle until Point B is reached. Also I'll gamble that if the test conditions were changed we might get different temperatures."

"Bravo, my friend!" he exclaimed. "We are progressing nobly. This Point B is the one we are most interested in. Let's see what we can do with it. At this Point B, since the fracture is *completely* brittle, we can use our formula for flow stress as the formula for fracture stress, since the two coincide here. And it appears reasonable to assume that the fracture stress which produces completely brittle fracture in the Charpy bar should be the same as that which produces completely brittle fracture of the metal in service. The fractures are the same. Would you agree, Izzy?"

I nodded agreement, remarking, "It sounds reasonable, but I seem to remember that fracture stress varies somewhat with strain rate and temperature."

Yukan laughed as he replied, "That's right, but the variation turns out to be small enough so we don't need to consider it right now. I think we can agree that if the appearance of two fractures in a given piece of metal is the same, then the stress causing those fractures is the same.

"Now let's do a little more mathematics and write" (and here the pencil and paper came in again):

$$(\Sigma)_s e^{x \div T_s} = (\Sigma)_c e^{x \div T_c}$$

Where $(\Sigma)_s$ = Strain rate in the metal in service
$(\Sigma)_c$ = Strain rate in Charpy bar at base of notch
T_s = Absolute temperature in service above which no completely brittle fracture is to occur (temperature to be selected)
T_c = Absolute temperature of Point B
x = A metal constant (about 5000 for constructional steels)

He paused and regarded me with an amused look for a moment. Before he could continue I remarked, "How do we know what these strain rates might be? Do we have to make a guess at it?"

"Not exactly," he answered. "But let us say, for example, that in service we do not want a completely brittle fracture at temperatures above −100° F. Then in the equation T_s becomes about 200 (the equivalent on the absolute scale of −100° F.). And from some experimental data and theoretical calculation we can say that the strain rate at the Charpy notch is about 650 in. per in. per sec. That's a value for $(\Sigma)_c$ in our equation. That gives us three of the five unknowns in our equation, and if we can arrive at some practicable

value for the strain rate of the metal in service we can solve the equation for T_c and that would locate Point B on our curve for us — the temperature for completely brittle fracture."

At this point I couldn't forget that he had not answered my previous question about strain rate, so I interrupted, "That sounds logical, but I am still very much interested in how you intend to obtain a value for what you have labeled $(\Sigma)_s$. This strain rate of the metal in service seems to be a rather intricate problem for the average engineer. He usually doesn't have precise data to work with. Does he have to guess, or use his factor of safety again?"

My friend Yukan grinned as he said, "It's about time I was starting home for supper, but let's walk past my office, where I have a little information about this in my notebook. Also I'll need a book of logarithms. Also you'll need a little fresh air to brace you for the freshman mathematics you're going to have to use."

It wasn't long before we were at Dumbkoff's desk, and he carried on:

"I think we can get a good value for strain rate of metal in service by simple calculation. Suppose we have an automobile axle that is made of heat treated steel and it has a yield strength of 100,000 psi., and that the severest bump it will get on a country road will take 0.01 sec. (pretty fast). Now we can easily figure how far this axle metal will move when it has reached its yield point by dividing that figure by the modulus of elasticity, thus:

$$\frac{100{,}000}{30{,}000{,}000} = 0.0033 \text{ in. per in.}$$

"Now we have already assumed that this movement will take 0.01 sec. The strain rate then will be

$$(\Sigma)_s = \frac{0.0033}{0.01} = 0.33 \text{ in. per in. per sec.}$$

"Eureka!"

So without further delay my good friend Yukan wrote out the equation, made the substitutions, and solved for the location of Point B. I copied the mathematics. Here is the dope:

$$(\Sigma)_s \varepsilon^{x \div T_s} = (\Sigma)_c \varepsilon^{x \div T_c}$$

$$\ln (\Sigma)_s + \frac{x}{T_s} = \ln (\Sigma)_c + \frac{x}{T_c}$$

$$\frac{x}{T_c} = \frac{x}{T_s} + \ln (\Sigma)_s - \ln (\Sigma)_c$$

$$\frac{1}{T_c} = \frac{1}{T_s} + \frac{\ln \frac{(\Sigma)_s}{(\Sigma)_c}}{x}$$

$$T_c = \frac{1}{\frac{1}{T_s} + \frac{1}{x} \ln \frac{(\Sigma)_s}{(\Sigma)_c}}$$

$$T_c = \frac{1}{\frac{1}{T_s} + \frac{2.3}{x} \log_{10} \frac{(\Sigma)_s}{(\Sigma)_c}}$$

$$T_c = \frac{1}{\frac{1}{200} + \frac{2.3}{5000} \log_{10} \frac{0.33}{650}}$$

$$T_c = \frac{1}{0.0035}$$

$$T_c = 285.7°K. = 12.7°C. = 54.8°F.$$

"This is the answer we've been looking for!" exclaimed Yukan triumphantly. "Do you comprehend what this figure means, Izzy?' he asked, regarding me with a look of satisfaction, and went on rapidly before I could reply, "We have calculated here the location of Point B of the transition temperature curve (as determined on Charpy machines in your laboratory) which should indicate the absence of complete brittleness in the metal in service at temperatures above −100° F. under strain rates of less than ⅓ in. per in. per sec." He paused expectantly. "If a metal under your laboratory Charpy tests had an intercept with the X-axis *above* 55° F., it would break in a completely brittle manner in the service we have assumed. Any metal whose intercept was *below* 55° F. would have at least some fibrous or ductile portions in a fracture under those conditions — probably it would not break at all."

I was silent for a moment or two thinking about this idea he had been explaining. It appeared to me to be very interesting but I couldn't forget one puzzling question which had remained from the beginning of his discussion. It bothered me.

"Yukan", I said, "this idea you have explained to me is very intriguing and may have some practical value when fully understood. Thanks for your interest in my problem. You have been very helpful and I appreciate it. However, one question plagues me: How can I determine just how much plastic flow is necessary, under the service conditions imposed, to prevent a start of fracture?"

"That is the $64 question," he replied, rising to his feet. "This principle we have been discussing leaves some points unanswered but I believe it may be useful. At present I do not believe we can go further in a practical way by mathematical analysis. Well, I see it is nearly dinnertime, and the Mrs. will be after me. We have guests in for the evening."

We walked toward his home together, through the brisk winter afternoon, and I imagined a welded freighter breasting a North Atlantic storm, and I wondered whether the formula and the natural logarithms would comfort the skipper and make him feel sure he could make port without damage. I am still wondering.

CORRESPONDENCE

The Australian Institute of Metals

MELBOURNE, AUSTRALIA

To the Readers of METAL PROGRESS:

I am writing primarily to acquaint you with a new metallurgical society in Australia.

Although our population (approximately 7 millions) is small by U. S. standards, our metallurgical education, practice and research are well advanced. A number of our universities provide degree courses in metallurgy and metallurgical engineering, and at one University, namely Melbourne, we have both a Professor of Metallurgy and a Professor of Metallurgical Research. In addition, diploma courses are provided by technical colleges in the larger cities.

Metallurgists and people interested in metallurgical work are catered for by two major technical societies, the Australasian Institute of Mining and Metallurgy, whose influence is mainly in the fields of mining, ore dressing and production of metals, and the Australian Institute of Metals. It is the latter society with which I shall deal here. The Australian Institute of Metals is very similar in its scope to the American Society for Metals. Both societies are confined mainly to the fields of use, working and treatment of metals, and research problems of a fundamental nature. They are also similar in that they are not strictly professional bodies whose membership is governed by the possession of certain minimum academic qualifications.

The activities of the Australian Institute are also analogous to those of the A.S.M. Top control is vested in a Federal Council which delegates executive authority to a smaller Federal Executive body and various sub-committees for special activities. Corresponding to your Chapters we have Branches in, at present, five principal cities and centers of metallurgical activity located at Adelaide, S.A., Melbourne, Vic., Sydney, N.S.W., Newcastle, N.S.W., and Port Kembla, N.S.W. Each Branch has its own local Branch Council which is responsible for its own finances (under control of the Federal Council) and for holding technical meetings and social functions. Melbourne Branch has two Divisions — Physical Metallurgy, catering mainly for people interested in research activities, and Metals Treatment, for people whose main interests are industrial. Each of these Divisions holds a monthly technical meeting.

The total membership is at present between 1500 and 2000 and is growing rapidly. The Institute was formed by amalgamation from a number of local metallurgical societies which started spontaneously in the different centers as far back as the early nineteen thirties. All these societies had kindred interests, and just before the last war a move was made toward amalgamation and incorporation under the Companies Acts, but this was delayed by the war; as a result incorporation was effected only in 1946.

In the past, technical papers from all branches have been published in, and by arrangement with, a local journal, *The Australasian Engineer*, a copy of which is distributed to each member; and it has been left to the individual branches, if they so desired, to publish volumes of selected reprints from time to time. However, now that incorporation has been completed it has been decided to publish an annual volume of *Transactions*, modest at first, which will include proceedings of the annual Federal Convention and reprints of selected papers of high merit. For the time being *The Australasian Engineer* will continue to be the official journal for the publication of those papers considered to be of sufficiently high standard.

It is hoped that the brief description given above will enlighten readers on some of the activities of a kindred organization "down under".

The Secretary of the Australian Institute of Metals is Mr. R. S. Russell, who is located at "Collins House", 360 Collins St., Melbourne C.1., Victoria, Australia.

A. L. SIMMONS
Ammunition Factory
Department of Supply and Development

KEEPING BLUEPRINTS & SPECIFICATIONS IN STEP WITH PROGRESS

By L. E. Simon
Chief Metallurgist
Electro-Motive Div., General Motors Corp.
La Grange, Ill.

MANUFACTURE of diesel-electric locomotives started in comparatively recent years. As outlined in an article by the present author in *Metal Progress* for October 1947, General Motors acquired an engineering concern in this field known as Electro-Motive Co. 17 years ago, and built a new plant at La Grange. By 1938 operations at this point included three kinds of manufacture — *(a)* heavy-duty electric generators and traction motors, *(b)* diesel engines and *(c)* car bodies and trucks. The raw materials (including castings and forgings) are purchased competitively and include plastics, rolled steel in a variety of forms, gray iron and malleable iron castings, copper, copper alloys, aluminum alloys, mica products, fuel and lubricating oil, varnish, glass, and welding electrodes. These items are used in many diversified forms. The weight of finished product delivered in 1948 was 290,000,000 lb., about equivalent to one four-unit locomotive every working day.

Construction of such a commercial product with continued sales potential requires satisfactory levels of quality and cost. The materials entering the device and their manufacturing response are major factors in arriving at these objectives. Exclusive of fasteners, and counting the engine, generator and traction motors each as one part, there are about 14,000 pieces in a single locomotive unit — the major part of the weight being metal. It is apparent that the important problem of metallurgical control has many ramifications. There must be a balanced expenditure of effort between the engineering aspects of metallurgy, the inspection of incoming metal and finished parts, and process control metallurgy.

One phase of a balanced metallurgical activity in a manufacturing operation such as ours is the proper specification of basic materials, the systematic distribution of necessary information to all concerned (as by the proper notations on detailed drawings), and some simple scheme of making changes all along the line when some change in the material or the specification is necessary. It is now our purpose to discuss this particular subject as it is treated in the Electro-Motive plant.

The problem of unifying, systematizing and indexing the specifications is something that is likely to be disregarded until it becomes apparent that something *must* be done to prevent worse confusion.

In the early days of a commercial development, the dominant interest is in engineering improvements to meet environments encountered as the machines are put to use by the first customers. A later phase of successful operations recognizes the necessity for coordinating all aspects of engineering activity, whereupon the lack of uniformity in the early methods of handling of

Sheet A — Index to Electro-Motive Materials Manual

Index Sheet	Index No.*	Material Classification
Ferrous Metals		
B	0000 to 0099	Steel (carbon and alloy) bars and forgings
C	0100 to 0199	Steel (carbon or low alloy) sheet, plates, profiles, wire
D	0200 to 0299	Steel (special alloy only) sheets, plates, bars, forgings, wire and shapes. Also nickel alloys
E	0300 to 0399	Steel castings — carbon or alloy
F	0400 to 0499	Cast iron — plain, alloy or malleable
Welding Materials and Their Procedures and Practices		
G	0500 to 0599	Ferrous and nonferrous — rods, electrodes, flux, hard solders
Nonferrous Metals		
H	0600 to 0699	Copper and copper alloys — cast, wrought or shapes
I	0700 to 0799	Aluminum and its alloys — cast, wrought or shapes
J	0800 to 0899	Bearing materials and sintered (powder) metals
K	0900 to 0999	Metals (miscellaneous) — die cast, lead, plated coatings, soft solders
Nonmetallic Materials; Composite; Compounds; Miscellaneous		
L	1000 to 1099	Electrical and thermal insulating materials, including plastics of electrical use origin
M	1100 to 1199	Elastic and gasket — rubber, cork, asbestos gasket
N	1200 to 1299	Plastics, glass, composite of metal and nonmetals, cable and similar electrical material
O	1300 to 1399	Paints, lacquers and like finishing materials, and including insulation and varnishes
P	1400 to 1499	Miscellaneous unclassified materials — wheels, finish machined items and items not otherwise classified
Q	1500 to 1599	High temperature materials
R	1600 to 1699	Lubricants
V	2000 to 2100	Blanket authorizations for substitute materials
Finished and Semifinished Materials		
		Finished items requiring specifications, such as finish machined wrought steel wheels or springs, will be found under unclassified materials
		Semifinished materials, such as castings of heads or pistons, are listed under their respective titles, cast iron or malleable, as physical and chemical data qualify

*These numbers are not specification numbers. The specification number will appear on each specification. The index number is used for this manual and for the International Business Machine (IBM) code number. These numbers will be applicable for cross reference on the "IBM Use Cards", "Purchase Materials 'R' Cards", and "Bulk Material" cards, where affected. It will also be used the same as a "part number" when requisitioning manual sheets from blueprint files.

basic materials becomes apparent. In our case, this (plus other factors such as the scarcities during wartime, the invalidation of standard specifications, and changing price structures) resulted in a situation wherein a large number of blueprints carried a variety of notations concerning specifications, some of which were obsolete. In order to collect these many specifications under one cover and use a new system covering mandatory requirements, general information, and blueprint notation, it was decided to assign *all* specifications, old and new, an index number in addition to their specification number. Various specifications on a common type or class of steel or alloy are then collected in an index group to facilitate their use. The general index to our "Electro-Motive Materials Manual" (all $8\frac{1}{2}$ x 11-in. ring-binder sheets) is reproduced in Sheet A, alongside; Sheet B, opposite, gives the breakdown for steel (carbon and alloy) bars and forgings.

This general codification was one of the first steps taken in 1947 when the metallurgical section was made a part of the engineering department, and it was a part of an agreed-upon policy to serve as a general framework for specifications and their designation. This framework contained the following provisions:

1. Frequent changes of specification numbers by the originating societies or other organizations cause our blueprint designations to become obsolete. To avoid this, Electro-Motive specifications (EMS) numbers will be assigned to most of them. Thereafter only the text of the specification, rather than all affected prints, need be changed.

2. The desirability of using standard specifications in purchasing, to avoid aftercharges and to utilize terms standard to an industry, are obvious. For this reason, wherever commercial specifications are available they will be written verbatim, including the number designation (to which they will be purchased) on EMS specification sheets. (Example: On EMS specification show the A.S.T.M. number; if A.S.T.M. changes, then *only* the specification needs corrections.)

3. There will be a limited number of exceptions to the above, namely the use of S.A.E. designations for steel bars and forgings. These are quite stable, and have code numbers which are well established among our personnel. The introduction of EMS appellations for these steels would necessitate memorizing a new code, or frequent reference to the Materials Manual.

4. Specifications of the following principal societies and organizations will be covered hereafter under EMS numbers in all new or revised drawings:

American Assoc. of Railroads (A.A.R.)
American Society for Testing Materials (A.S.T.M.)
Aeronautical Materials Specifications (AMS)
American Iron and Steel Institute (A.I.S.I.)
Federal Specifications Board
Army-Navy (A-N)
U. S. Navy
National Electrical Manufacturers Assoc. (N.E.M.A.)

Sheet B — Index to Electro-Motive Materials Manual
Steel (Carbon and Alloy) Bars and Forgings

Index No.	Common Designation	Material	Type
0000	General information on steel		
0003	S.A.E. 1020	Steel	Low carbon steel machine parts
0005	S.A.E. 1035	Steel	
0006	S.A.E. 1045	Steel	
0007	S.A.E. 1060	Steel	Bars, plates and forgings
0008	MS-4361	Steel	Welded car structures
0009	EMS-69	Steel	Wrought steel welding fittings
0011	S.A.E. 1090	Steel	Bars, plates and forgings
0012	S.A.E. 1095	Steel	Bars, plates and forgings
0013	EMS-80	Polished carbon steel drill rod	
0020	S.A.E. 1112	Steel	Bessemer screw stock
0021	S.A.E. 1117	Steel	Free-machining, carburizing quality
0022	S.A.E. 1141	Steel	Free-machining, through hardening in 1-in. sections
0035	S.A.E. 3140	Steel	Through hardening alloy in medium sections
0036	S.A.E. 4340	Steel	Through hardening alloy in heavy sections
0038	S.A.E. 6145	Steel	Through hardening alloy in medium sections; springs
0050	S.A.E. 4615	Steel	Carburizing alloy
0055	S.A.E. 4815	Steel	Carburizing alloy
0059	EMS-70	Steel forgings	Locomotive, truck and car structures
0060	EMS-71	Alloy spring steel	
0061	EMS-72	Oil tempered carbon steel spring wire	
0062	EMS-73	Oil tempered carbon steel valve spring wire	
0063	EMS-74	Music wire spring steel	
0064	EMS-75	Oil tempered Cr-V steel; valve spring wire	
0065	EMS-76	Hot wound carbon spring steel	
0075	EMS-50	Seamless cold drawn mechanical tubing	
0076	EMS-51	Ditto	Finish annealed
0077	EMS-52	Ditto	Bright soft annealed
0078	EMS-53	Ditto	Turk's head shaped

Exceptions: General Motors' (G.M.) specifications for standard items only, and Society of Automotive Engineers (S.A.E.) specifications will be called by their titles.

5. All MS specifications (our old materials specification numbers) will be converted to EMS, except those few which are widely used on current prints or are considered too well established in our business to be disturbed. (Examples: MS-4361 covering plain carbon steel for welded structures and MS-4398, carbon-molybdenum steel.) MS specifications have heretofore been blueprint room records. Those which are standard items and bulk materials have been assigned "8,000,000" numbers and continue as blueprint records.

6. Where no commercial specification is available, we will continue to write our own under EMS numbers.

Content of Individual Specification

Insofar as an individual specification was concerned, it was agreed that it should accomplish the following:

1. Define the material so that it may be properly ordered, inspected and paid for.
2. Define the material so the supplier may understand the qualities which must be furnished and billed.
3. Furnish information to the designer as to the material's utility in application.
4. Indicate correct blueprint notation.
5. Furnish information to assist tooling, planning, warehousing, and manufacturing.
6. Provide measurable limits of qualities for purposes of inspection. These limits should be related to processability and product performance.

To accomplish these aims our material specifications are divided into three parts:

1. Mandatory requirements.
2. General information (nonmandatory requirements).
3. Blueprint notation.

Number 1 covers the factors which are normally considered as a specification. Numbers 2 and 3 cover the other matters of information related to the specification, which outline its field of application and standardize the manner of calling out the specification on a blueprint. The scheme outlined above will localize under one cover all basic material references and facilitate the handling of questions about the material arising in the shop, drafting room and design department.

It has been our intention by these tactics to encourage *all* our personnel to become familiar with the basic information available within the metallurgical division. All drawings are reviewed by an engineer well informed about the properties of materials, but the drafting room is usually able to apply the proper material prior to referring the tracing to him. Of course, he will change a small percentage of the tracings referred for his approval because of his specialist's knowledge of machinability, weldability or other processing operations, original cost, quality factors, and adaptability to our shop equipment.

Our engineering material specifications generally attempt to control quality of the finished part; special features to facilitate manufacturing are added by the master mechanic's department at the time of "preliminary engineering release". The maximum latitude permissible is desirable at this period of the development of a new part, in order that the most economic finishing methods may be applied. For instance, it may be sufficient

MATERIALS MANUAL — Index No. 0321

MATERIAL SPECIFICATION — EMS- 16

ELECTRO-MOTIVE DIVISION
GENERAL MOTORS CORPORATION
LA GRANGE, ILLINOIS

4-11-47
W. J. Brechtel

NAME: MEDIUM STRENGTH STEEL CASTINGS

REQUIREMENTS:-

Material ordered to these specifications shall meet all of the mandatory requirements of A.A.R. M-201-45 Grade B, excerpts from which appear hereunder along with required E.M.D. modifications.

Chemical Composition:

Manganese, per cent max.	0.85
Phosphorus, per cent max.	0.05
Sulphur (Basic, max.	0.05
Sulphur (Acid, max.	0.06

Unless otherwise specified, the content of elements other than those designated above shall be selected by the manufacturer to obtain the physical properties specified.

Heat Treatment:

All castings shall be normalized and tempered or full annealed. The choice between the two treatments shall be the option of the vendor.

Physical Tests:

Tensile Strength, p.s.i., min.	70,000
Yield Point, p.s.i., min.	38,000
Elongation, per cent in 2", min.	24
Reduction of Area, per cent, min.	38
Hardness, Brinell	137-170

GENERAL:- (Not mandatory requirements)

This material is intended for general use in locomotive structures where medium strength cast steel is suitable. It is not considered a welding grade.

DRAFTING INFORMATION:-

The following shall appear on the blue print:

MATERIAL: EMS 16 CAST STEEL

then allows the master mechanic's department to apply 1020 steel as a hot rolled bar, a cold finished bar, a forging, or scrap ends of the specified composition — depending on the quantity rate scheduled and the tooling available. The local carburizing may of course be accomplished in several ways. In another part the field function may require the properties to be those of a closed die forging; this will be so stated on the engineering drawing, thereby restricting the material and narrowing the applicable manufacturing techniques.

One portion of our materials policy provides for the use of commercial specifications such as A.S.T.M. or A.A.R. wherever possible, but to call for them under *our* number. This allows us to take care of such a circumstance as the society invalidating the specification or making an undesirable change. We merely change to a new and acceptable specification under our same divisional specification number, and this avoids any extensive blueprint revisions. When our specification calls for a commercial specification by our own number, the salient features of the commercial specification are written on our specification sheet as well as other supplementary information. The adjoining engraving reproduces EMS-16, a typical specification (original size 8½ x 11 in.)

(for purposes of engineering function) that the qualities of a 0.20% carbon steel with certain areas carburized will suffice. Simply specifying "S.A.E. 1020 steel with required areas carburized"

New Steel for 3000 Details

Where commercial specifications do not adequately apply for our purpose, a divisional

MS-4361; Plain Carbon Steel for Welded Structures

SCOPE — This specification covers low-carbon steel bars, bar size shapes, plates and structural shapes for locomotive or railroad car structures, and plates for general use, all compositions so adjusted as to maintain a desired level of physical properties and weldability.

Under a further qualitative restriction, designated as "firebox quality", it covers similar plates subject to a homogeneity test.

Items appearing elsewhere in this specification other than under the section headed "REQUIREMENTS" are not to be construed as expressed or implied obligations upon the vendor.

REQUIREMENTS "*A*" — The following applies to bars, shapes and plates:

The standards and practices set forth in the manuals of the American Iron and Steel Institute shall govern in all matters pertaining to this material, wherever such rules are applicable, such as standards of quality, sampling, check analysis, tolerances, identification and marking, for the type of steel specified.

No further definition or interpretation, either restricting or liberalizing the quality of this steel, shall be made beyond the specific description stated herein, except by revision of this specification.

"*B*" — *Bars and Bar Size Shapes* (shapes up to 3 in. in length of cross section). Chemical composition (A.I.S.I. C1016 steel) ladle analysis: Carbon 0.13 to 0.18%, manganese 0.60 to 0.90%, phosphorus 0.04% max., sulphur 0.05% max.

"*C*" — *Structural Shapes and Plates.* Chemical composition, ladle analysis for sizes ¾ in. in thickness of cross section and under: Carbon 0.13 to 0.20%, manganese 0.30 to 0.60%, phosphorus 0.04% max., sulphur 0.05% max. Ladle analysis for sizes over ¾ in. in thickness of cross section: Carbon 0.15 to 0.22%, manganese 0.30 to 0.60%, phosphorus 0.04% max., sulphur 0.05% max.

Sheet Steel Sizes Composition Waiver: Wherever this material is specified for plates and such material is less than ¼ in. in thickness and falls into a sheet or strip classification in the A.I.S.I. tables, such material need not conform to any requirements other than those for "hot rolled commercial quality sheet steel", unless further qualified on the order.

"*D*" — *Firebox Quality Plates:* Plates ordered to "MS-4361 firebox quality" shall meet the requirements stated for plates under "*C*", above. In addition, a homogeneity test, as prescribed for firebox quality plates under A.S.T.M. A285-46, shall be made and the material shall meet it.

GENERAL (not mandatory requirements) — The statements made under REQUIREMENTS "*A*" shall not interfere with the function of the usual written interdepartmental authorizations where substitutions of other steels are necessary; neither shall they interfere with drawing notes, or processing instructions qualifying surface condition such as pickling, oiling or other similar requirements which do not affect the physical properties of the basic material.

Physical Properties: (Information for stress computations)

Tensile strength	50,000 psi. min.
Yield point	27,500 psi. min.
Elongation in 2 in.	22% min.

This steel is primarily intended

Proper identification of the correct material on blueprints, so that designer, draftsman, purchasing agent, inspector, mechanic or heat treater can be properly informed, is a basic requirement of modern mass production. Adequate provision for necessary revisions becomes more difficult as the final machine becomes more complex. In this article L. E. Simon describes methods used by Electro-Motive Division, G.M.C., constructors of diesel-electric locomotives, each unit containing about 14,000 parts.

specification is prepared. Again the use of our own number permits the maximum adaptability and quick response to changing requirements.

An example of this occurred recently. In the early days of our company the design engineers wanted to use a low-alloy high-tensile welding grade of steel for certain applications in the car body. These steels were so new at the time that it was decided to write our own specification covering a manganese-molybdenum alloy steel; it was numbered MS-4398. This steel served satisfactorily for many years. In the meantime, the low-alloy high-tensile steels evolved commercially until our tests indicated that the commercial products were equivalent to our MS-4398, and the latter was priced as an alloy base taking an extra as compared to the low-alloy high-tensile price structure on the various commercial grades. At our current consumption rate this meant a difference of $250,000 per year. The number MS-4398 appeared on several thousand different drawings. In order to realize the cost savings quickly and without hundreds of hours of drafting time for changing tracings, we merely rewrote the MS-4398 specification to cover the new material.

Specification MS-4361, reproduced in the footnote, is another excellent example of our divisional specifications. It covers plain carbon steels of welding quality, extensively applied in our car body structure. Again, the utility of this method of handling specifications was recently illustrated. For many years MS-4361 contained limitations on both chemistry and physical properties. A probability plot of the physical and chemical data on many lots of this steel, as received, indicated that certain physical property minimums could be guaranteed to the designer if specified chemical limits were maintained. The mandatory physical property limitations were therefore deleted from the specification and a saving of $80,000 per year was realized without any loss in quality.

One important class of steel which we use extensively is covered by the G.M. and the S.A.E. specifications. The long-range stability and wide shop knowledge concerning these materials caused us to use these numbers directly on the blueprints. Since we heat treat these grades, we decided to place the heat treatment and hardness limits on blueprints, as follows:

Drafting Information

The following notes shall appear on the blueprint:

MATERIAL: S.A.E. 3140 Steel.
HEAT TREATMENT: Heat to 1525° F.
Quench in oil.
Temper to Rockwell C-28 to 32.

for locomotive car structures. For this purpose the specification is drawn to requirements which provide a definite minimum strength as high as practical in carbon steel, consistent with the weld characteristics experience has proven necessary for safe welds with production welding practices in locomotive structures. It covers the three commercial shapes in which these qualities are also matters of principal importance.

The secondary purpose of this specification is to provide for the optional use of either bar stock, shapes, or plates, wherever the qualities of plate steel are satisfactory, for the processing of parts without necessity of changing prints to permit the use of shapes of raw stock most suitable to processing equipment.

The intended applications involve little use of forgings, heat treatment, or machining. The necessary qualities for the intended purpose are also dissimilar to those of sheet steel or deep drawing plate stock. For this reason the material is not purchased to forging, heat treating or deep drawing quality. Neither is it intended for sheet $\frac{5}{16}$ in. and under in thickness. Drawings for machine parts, other than those which may be made of plate, should not specify this steel.

Materials Manual References to Related Materials: For forgings of comparable strength, of welding quality, or for machine parts made from bar stock, see S.A.E. 1020 — Index No. 0003. For sheet steel $\frac{5}{16}$ in. or under in thickness, see EMS-55 — Index No. 0100. For plate with deep drawing qualities, see EMS-62 — Index No. 0108.

The use of firebox quality plate is intended only for those applications where the greatest freedom from internal segregations or laminations is necessary. All MS-4361 is of such composition that in normal practice it will be at least semikilled, which in itself provides some reduction of segregations. As sizes increase, with resultant increase of likelihood of voids which have failed to weld up in rolling, a point is reached where the mills resort to full silicon killing. It is mandatory that we pay for killed steel, on both MS-4361 and MS-4361 firebox quality, when we reach the following sizes: Plates in excess of $1\frac{1}{2}$ in. in thickness, rounds or squares 3 in. and over, and bars 40.8 lb. per ft. and over. Specifying "firebox quality" does not assure complete freedom from segregations but, due to larger amounts of discard cropped from the ingots, such voids are reduced to a minimum.

DRAFTING INFORMATION — The following designation shall appear on the blueprint:

Material: MS-4361 Steel

Where firebox quality plate is required, the following designation shall be used:

Material MS-4361 Firebox Quality Steel

A.W.S. 6020; Class E-6020, Heavy Coated Metallic Arc Welding Electrode

N.E.M.A. Color Code: Blue Primary

REQUIREMENTS — This welding electrode shall meet the requirements prescribed by A.W.S.-A.S.T.M. A233-45T or G.M. 3524-M specifications.

Procedure: This electrode shall be used for flat position and horizontal fillet welding only. It is for use with direct current straight polarity (elec-

Information About Heat Treatment

It should be noted in passing that explicit and detailed instructions have been worked out to guide the heat treatment of all standard items of production. Nevertheless it was thought desirable to include some metallurgical information in this specification so the draftsman, purchasing department — in fact, all personnel using the specification — would know something about the adaptability of this material. These general items (not mandatory requirements for S.A.E. 3140) are worded as follows:

> This steel is used where the required physical properties, or size of section, exceed the limitations of S.A.E. 1141 steel.
>
> It will harden, in an oil quench, through a $1\frac{3}{4}$-in. cross section.
>
> Compared to S.A.E. 1141, it is less sensitive to reduction in hardness in quenching heavy sections or large loads of material. It has better strength, particularly in torque and in shock load applications. The fatigue endurance limit is higher. The machinability, however, is markedly reduced.
>
> Common applications are axle shafts, small crankshafts, splined shafts, studs, some gears, and a wide variety of other machine parts requiring above-average strength in medium hard material.
>
> Information for stress computations: When heat treated as in the note in "Drafting Information", the minimum physical properties will be:

Tensile strength	135,000 psi. min.
Yield strength	105,000 psi. min.
Elongation in 2 in.	16% min.
Reduction of area	50% min.
Machinability rating (normalized)	40% of S.A.E. 1112

Information About Welding

Notations on blueprints concerning welding generally call for the size and type of weld required for the load. The specific A.W.S. type of electrode to be used is then called for on process procedures and drawings. As an example, A.W.S. C020-6030 are used on positioned weldments, and A.W.S. 6012-6013 or 6010-6011 on others.

A typical specification for electrodes is given in the footnote. It requires their purchase from an approved source, which approval is granted only after laboratory and shop tests. Currently this activity indicates that most electrode manufacturers' product will produce deposits of acceptable soundness, strength and ductility, but that there are definite differences within a given class of electrodes, particularly as regards deposition rates and efficiencies. Our program is to channel our purchases toward these higher performance electrodes by the use of our approved source list. Since we use in excess of 4,000,000 lb. of manual welding electrodes per year, a decrease in unit labor costs as a consequence of improved electrode performance will represent a substantial saving.

Authorization of Substitutes

One sheet in the materials book is devoted to blanket authorization for substituting currently applicable material for certain obsolete materials appearing on blueprints. (These blueprints are then revised as opportunity permits.) Such authorizations are grouped in three classes:

trode negative) or alternating current for horizontal fillet welds, and direct current either polarity or alternating current for flat position welding.

Size	Recommended Amperes	Volts
$\frac{1}{8}$ in.	100-140	24-28
$\frac{5}{32}$	120-180	26-30
$\frac{3}{16}$	175-250	28-33
$\frac{7}{32}$	200-325	30-36
$\frac{1}{4}$	250-400	30-36
$\frac{5}{16}$	350-450	32-38
$\frac{3}{8}$	400-500	34-40

GENERAL (not mandatory requirements) — This electrode is designed to produce flat or slightly concave horizontal fillets with either alternating current or direct current, and fillets and groove welds in the flat position. It is characterized by a spray-type arc and a heavy slag (well honeycombed on the under-side) which completely covers the deposit and can be readily removed.

When normal welding currents and technique are employed, penetration is considered to be medium. However, it is capable of operating satisfactorily at high currents, which results in deep penetration, particularly when such a technique is employed as in deep fillet welding.

This is essentially a mineral covered electrode. The slag-metal reactions are of such a nature that the electrode does not normally depend on gaseous protection. The covering is such that the slag is usually made up of iron oxide, manganese oxide and silica. Other constituents containing the oxides of aluminum, magnesium or sodium are present to modify the slag. Ferromanganese is used as the main deoxidizer. The quantities of basic oxides, acid silica and silicates, and deoxidizers must be carefully controlled to produce satisfactory operation and good weld metal. Sodium silicate is used as the binder. Core wire is usually 0.10 to 0.14% carbon steel.

This electrode is recommended for horizontal fillets for best quality and where rigid radiographic examination must be met. High deposition rates can be obtained with high quality on flat fillet and groove welds in heavy plate. This type of electrode is not generally used on thin sections due to increased warpage resulting from the higher currents usually employed.

The range of mechanical properties to be expected from the weld metal when deposited in accordance with the test procedures prescribed in the specifications is:

	As Welded	Stress Relieved
Tensile	62,000-68,000	60,000-66,000
Yield	52,000-58,000	47,000-53,000
Elongation	25-30	30-36
Reduction	40% min.	50% min.
Izod impact	50-70 ft-lb.	
Endurance limit	30,000-34,000	
Density	7.82-7.86	
Brinell hardness	150-170	

NOTE: Engineering approval of source is required for purchase.

DRAFTING INFORMATION — Drawings requiring weldments shall be sent to the welding engineering group for approval of welding symbols, welding electrode requirements and stress relief notes.

NOTE: These specifications were developed without considering whether patents may or may not be involved. In all cases, therefore, the supplier shall be required to assume patent liability.

Class I, Noninterchangeable, Mandatory, Unidirectional Substitutions, such as the following: "Where print specifies A.S.T.M. A-89 Grade B always use MS-4361 firebox quality." An authorization of substitute material is required to deviate from such instructions and to use the material shown on print.

Class II, Optional Unidirectional Substitutions, such as the following: "Where steel specified is S.A.E. 1120, S.A.E. 1117 may be used." No authorization of substitute material is required to make such changes.

Class III, Optional, Bidirectional, Interchangeable Substitutions, such as A.I.S.I. 8742 ⇌ N.E. 8744. No authorization of substitute material is required.

Aside from these changes that have been well assimilated, emergencies are always arriving. During the war, and ever since, scarcities have required special action in the form of an "Authorization for Substitute Material". The accompanying form (a ditto master) is originated by the purchasing department and requires approval by

AUTHORIZATION OF SUBSTITUTE MATERIAL

Date November 4, 1948 | Purchase Order No. 10810 | Part No. 9026572
Models Affected Engine | Serial No. 7592
Name of Part Injector Control Lever | Quantity 5000
Material Spec. on Dwg. & Routing SAE-1140
Material Spec. Suggested C-1137
Material Spec. Authorized C-1137 per vendor agreement below
Material is to be Segregated Thru Oper. # Heat treat | Or Routing Dated
Reason for Segregation Tempering temperature and hardenability differ
Signed John Jones
Special Processing Required

Reason for Request
Due to extended steel deliveries, vendor is unable to meet our delivery requirements unless he has permission to substitute C-1137 which is available. Vendor will hold carbon and manganese to high side.

Requested By A. J. [illegible] Purchasing Dept. | Date November 4, 1948
Manufacturing Approval F. S. Smith | Date 11-18-48
Metallurgical Approval John Jones | Date 11-9-48
Engineering Approval Harold T. Brown | Date 11-9-48

ELECTRO-MOTIVE DIVISION GENERAL MOTORS CORPORATION

the manufacturing department, the design engineering section, and the metallurgical section, whereupon the substitute is granted for a specific quantity of a given part number. Space is provided for revised heat treatment or special processing and to indicate segregation of the material if necessary. The form, after approval, is duplicated so as to provide wide distribution throughout the organization. It also accompanies the material into the shop.

Conclusion

While the specification practice outlined above is in some respects complicated by impingement of other divisional procedures, it has functioned satisfactorily to cover the material requirements for a type of motive power which has been accepted as outstanding in performance by the American railroads.

RAPID POLISH WITH DIAMOND HAND HONE

By L. P. Tarasov
and C. O. Lundberg
Research Laboratories, Norton Co.
Worcester, Mass.

THE USE of diamond abrasive for polishing metallographic specimens has grown considerably during the past two years, as shown by the sales of commercial diamond pastes for the purpose. Of course, diamond powders have been used for many years for cemented carbides, but now the process is being applied more and more to a wide variety of metals. Some methods and results are described by G. C. Woodside and Harold H. Blackett in an article entitled "Polishing Metallographic Specimens with Diamond Dust" in *Metal Progress* for June 1947, p. 945, which describes the polishing of molybdenum carbide, metallic molybdenum, high speed steel, and gray iron.

Among the outstanding advantages of diamond abrasive are that extremely hard substances and constituents can be polished with it, that the polishing is extremely rapid, and that inclusions are not likely to be pulled out. In general, it is restricted to the last stage, replacing the levigated alumina (and, at times, the preceding wet polishing operation with 600-grit abrasive); the earlier steps in the preparation are conventional.

The authors have found that the *intermediate* stages may be greatly speeded up by the use of a vitrified bonded diamond hand hone. A further advantage is that, with this new technique, the metallographer can rapidly polish high speed steels of the high-carbon, high-vanadium type. These are very difficult, or sometimes impossible, to polish by ordinary methods because the carbide particles are much harder than the emery abrasive in metallographic polishing paper. Cemented carbides and very hard nonmetallic materials can also be polished in a short time with the help of a diamond hand hone.

The first step consists, as usual, of obtaining a flat surface. This can be accomplished by grinding with a suitable 60 or 80-grit wheel on a surface grinder, or by using an 80-grit abrasive cloth belt

or disk. The second step is to impart to this surface a very good intermediate finish in a single stage by the use of a 600-grit diamond hand hone.* This is used in conjunction with a paste of 600-grit silicon carbide abrasive suspended in a light oil or kerosene.

The honing technique is illustrated in the adjoining half tone. The paste is spread over a hardened steel block which has been ground as flat as possible. The hone is rubbed on this block to retain the flatness of the diamond section and also to dress it. Then the hone, together with some of the silicon carbide paste which adheres to it, is rubbed over the metallographic specimen. One or two minutes of honing in this manner is found to remove the coarse scratches left from the first step and to leave a set of very fine scratches, which can be easily removed in a final polishing operation, as described later. The flatness of the surface can be preserved to the same degree with a hand hone as with the conventional polishing methods.

The question may well be raised as to the function of the loose 600-grit silicon carbide powder. If the metallographic surface is honed without its help, it will be found the diamond hone stops cutting almost immediately. Similarly, silicon carbide applied to the surface of the specimen by a dummy hone containing no diamond will also fail to cut and remove metal. Thus, the silicon carbide appears to keep the diamond hone sharp by continuously dressing it during the honing operation.

In order to explore the possibilities of the diamond honing technique, a wide variety of metals and other materials were polished in the form of metallographic specimens mounted in bakelite. These were as follows, in the order of decreasing hardness: molded boron carbide; aluminum oxide abrasive; a hard refractory of unknown composition; a cemented carbide; hardened high-carbon, high-vanadium, high speed steel; hardened S.A.E. 52100 steel; 18-8 stainless steel; gray iron; and a sintered copper-tin powder compact. Except for the boron carbide, the specimens were diamond honed sufficiently in one minute to remove all traces of the grinding scratches and to leave the surface ready for final polishing. Boron carbide required four minutes of honing to attain the requisite finish.

The final polishing was done on a wet rotating silk cloth lap, impregnated with a small amount of fine diamond powder, six microns and finer. Other types of cloth commonly used for metallographic polishing with levigated alumina were also found to be suitable. One minute of polishing the harder materials with the diamond powder resulted in a satisfactory finish, but left a few extremely fine scratches in the softer materials and also in the hardened 52100 steel. These scratches can be eliminated by further polishing for a short time with even finer diamond powders, commercially available in the form of pastes, or with levigated alumina. An alternative method, which is satisfactory for the softer metals, is to polish with levigated alumina directly after the diamond honing operation.

The quality of the polished surface, obtained in a very few minutes from the ground surface, was at least as good as obtained by the conventional polishing techniques and in a number of instances was definitely better. Particularly superior results were achieved on the nonmetallics and the cemented carbides, which we normally prepare on a Graton-Vanderwilt automatic mineralogical polishing machine and were generally found to be somewhat pitted. Diamond honing minimized pitting appreciably. For instance, the refractory material of unknown composition pitted so badly when a reasonably good finish was being approached on the automatic machine that microscopic examination was impossible; diamond honing, however, gave a surface that could be examined in detail at high power.

Thus, the new diamond honing technique not only greatly speeds up the intermediate polishing stages, but also satisfactorily prepares surfaces for microscopic examination which would otherwise be difficult or even impossible to polish.

Use of a Diamond Hone in Smoothing Hard Specimen Mounted in Bakelite Is Simplicity Itself

*Suitable for this purpose is a Norton ¼ by $\frac{7}{16}$ by 4-in., D600-V$\frac{7}{16}$ (Type DH1, $\frac{7}{16}$ by 1-in. diamond section) vitrified bonded diamond hone.

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"H" Steels; Chemical Composition Ranges

S.A.E. or A.I.S.I. Designation	Chemical Composition (Subject to Permissible Variations)					
	C	Mn	Si	Ni	Cr	Mo
1320 H	0.17/0.24	1.50/2.00	0.20/0.35	—	—	—
1330 H	0.27/0.34	1.50/2.00	0.20/0.35	—	—	—
1335 H	0.32/0.39	1.50/2.00	0.20/0.35	—	—	—
1340 H	0.37/0.45	1.50/2.00	0.20/0.35	—	—	—
2330 H	0.27/0.34	0.55/0.85	0.20/0.35	3.20/3.80	—	—
2512 H	0.08/0.15	0.35/0.65	0.20/0.35	4.70/5.30	—	—
2515 H	0.11/0.18	0.35/0.65	0.20/0.35	4.70/5.30	—	—
2517 H	0.14/0.21	0.35/0.65	0.20/0.35	4.70/5.30	—	—
3120 H	0.17/0.24	0.55/0.85	0.20/0.35	1.00/1.50	0.50/0.80	—
3130 H	0.27/0.34	0.55/0.85	0.20/0.35	1.00/1.50	0.50/0.80	—
3135 H	0.32/0.39	0.55/0.85	0.20/0.35	1.00/1.50	0.50/0.80	—
3140 H	0.37/0.45	0.60/0.95	0.20/0.35	1.00/1.50	0.50/0.80	—
3310 H	0.07/0.14	0.35/0.65	0.20/0.35	3.20/3.80	1.35/1.75	—
3316 H	0.13/0.20	0.35/0.65	0.20/0.35	3.20/3.80	1.35/1.75	—
4047 H	0.44/0.52	0.60/0.95	0.20/0.35	—	—	0.20/0.30
4053 H	0.49/0.57	0.70/1.05	0.20/0.35	—	—	0.20/0.30
4063 H	0.59/0.69	0.70/1.05	0.20/0.35	—	—	0.20/0.30
4068 H	0.62/0.72	0.70/1.05	0.20/0.35	—	—	0.20/0.30
4130 H	0.27/0.34	0.35/0.65	0.20/0.35	—	0.80/1.15	0.15/0.25
4132 H	0.30/0.37	0.35/0.65	0.20/0.35	—	0.80/1.15	0.15/0.25
4135 H	0.32/0.39	0.60/0.95	0.20/0.35	—	0.80/1.15	0.15/0.25
4137 H	0.35/0.43	0.60/0.95	0.20/0.35	—	0.80/1.15	0.15/0.25
4140 H	0.37/0.45	0.70/1.05	0.20/0.35	—	0.80/1.15	0.15/0.25
4142 H	0.40/0.48	0.70/1.05	0.20/0.35	—	0.80/1.15	0.15/0.25
4145 H	0.42/0.50	0.70/1.05	0.20/0.35	—	0.80/1.15	0.15/0.25
4147 H	0.44/0.52	0.70/1.05	0.20/0.35	—	0.80/1.15	0.15/0.25
4150 H	0.46/0.54	0.70/1.05	0.20/0.35	—	0.80/1.15	0.15/0.25
4317 H	0.14/0.21	0.40/0.70	0.20/0.35	1.50/2.00	0.35/0.65	0.20/0.30
4320 H	0.16/0.23	0.40/0.70	0.20/0.35	1.50/2.00	0.35/0.65	0.20/0.30
4337 H	0.35/0.43	0.55/0.85	0.20/0.35	1.50/2.00	0.65/0.95	0.20/0.30
4340 H	0.37/0.45	0.60/0.95	0.20/0.35	1.50/2.00	0.65/0.95	0.20/0.30
4620 H	0.17/0.24	0.40/0.70	0.20/0.35	1.50/2.00	—	0.20/0.30
4621 H	0.17/0.24	0.60/0.95	0.20/0.35	1.50/2.00	—	0.20/0.30
4640 H	0.37/0.45	0.55/0.85	0.20/0.35	1.50/2.00	—	0.20/0.30
4812 H	0.10/0.17	0.30/0.60	0.20/0.35	3.20/3.80	—	0.20/0.30
4815 H	0.12/0.19	0.35/0.65	0.20/0.35	3.20/3.80	—	0.20/0.30
4817 H	0.14/0.21	0.35/0.65	0.20/0.35	3.20/3.80	—	0.20/0.30
4820 H	0.17/0.24	0.45/0.75	0.20/0.35	3.20/3.80	—	0.20/0.30
5135 H	0.32/0.39	0.55/0.85	0.20/0.35	—	0.75/1.10	—
5140 H	0.37/0.45	0.60/0.95	0.20/0.35	—	0.65/0.95	—
5145 H	0.42/0.50	0.60/0.95	0.20/0.35	—	0.65/0.95	—
5150 H	0.46/0.54	0.60/0.95	0.20/0.35	—	0.65/0.95	—
6150 H	0.46/0.54	0.60/0.95	0.20/0.35	—	0.80/1.15	(0.15 min. V)
8617 H	0.14/0.21	0.60/0.95	0.20/0.35	0.35/0.75	0.35/0.65	0.15/0.25
8620 H	0.17/0.24	0.60/0.95	0.20/0.35	0.35/0.75	0.35/0.65	0.15/0.25
8622 H	0.20/0.27	0.60/0.95	0.20/0.35	0.35/0.75	0.35/0.65	0.15/0.25
8625 H	0.22/0.29	0.60/0.95	0.20/0.35	0.35/0.75	0.35/0.65	0.15/0.25
8627 H	0.25/0.32	0.60/0.95	0.20/0.35	0.35/0.75	0.35/0.65	0.15/0.25
8630 H	0.27/0.34	0.60/0.95	0.20/0.35	0.35/0.75	0.35/0.65	0.15/0.25
8632 H	0.30/0.37	0.60/0.95	0.20/0.35	0.35/0.75	0.35/0.65	0.15/0.25
8635 H	0.32/0.39	0.70/1.05	0.20/0.35	0.35/0.75	0.35/0.65	0.15/0.25
8637 H	0.35/0.43	0.70/1.05	0.20/0.35	0.35/0.75	0.35/0.65	0.15/0.25
8640 H	0.37/0.45	0.70/1.05	0.20/0.35	0.35/0.75	0.35/0.65	0.15/0.25
8641 H*	0.37/0.45	0.70/1.05	0.20/0.35	0.35/0.75	0.35/0.65	0.15/0.25
8642 H	0.40/0.48	0.70/1.05	0.20/0.35	0.35/0.75	0.35/0.65	0.15/0.25
8645 H	0.42/0.50	0.70/1.05	0.20/0.35	0.35/0.75	0.35/0.65	0.15/0.25
8647 H	0.44/0.52	0.70/1.05	0.20/0.35	0.35/0.75	0.35/0.65	0.15/0.25
8650 H	0.46/0.54	0.70/1.05	0.20/0.35	0.35/0.75	0.35/0.65	0.15/0.25
8655 H	0.50/0.60	0.70/1.05	0.20/0.35	0.35/0.75	0.35/0.65	0.15/0.25
8660 H	0.55/0.65	0.70/1.05	0.20/0.35	0.35/0.75	0.35/0.65	0.15/0.25
8720 H	0.17/0.24	0.60/0.95	0.20/0.35	0.35/0.75	0.35/0.65	0.20/0.30
8735 H	0.32/0.39	0.70/1.05	0.20/0.35	0.35/0.75	0.35/0.65	0.20/0.30
8740 H	0.37/0.45	0.70/1.05	0.20/0.35	0.35/0.75	0.35/0.65	0.20/0.30
8742 H	0.40/0.48	0.70/1.05	0.20/0.35	0.35/0.75	0.35/0.65	0.20/0.30
8745 H	0.42/0.50	0.70/1.05	0.20/0.35	0.35/0.75	0.35/0.65	0.20/0.30
8747 H	0.44/0.52	0.70/1.05	0.20/0.35	0.35/0.75	0.35/0.65	0.20/0.30
8750 H	0.46/0.54	0.70/1.05	0.20/0.35	0.35/0.75	0.35/0.65	0.20/0.30
9260 H	0.55/0.65	0.70/1.05	1.80/2.20	—	—	—
9261 H	0.55/0.65	0.70/1.05	1.80/2.20	—	0.05/0.35	—
9262 H	0.55/0.65	0.70/1.05	1.80/2.20	—	0.20/0.50	—
9437 H	0.35/0.43	0.85/1.25	0.20/0.35	0.25/0.65	0.25/0.55	0.08/0.15
9440 H	0.37/0.45	0.85/1.25	0.20/0.35	0.25/0.65	0.25/0.55	0.08/0.15
9442 H	0.40/0.48	0.95/1.35	0.20/0.35	0.25/0.65	0.25/0.55	0.08/0.15
9445 H	0.42/0.50	0.95/1.35	0.20/0.35	0.25/0.65	0.25/0.55	0.08/0.15

*Sulphur content 0.040/0.060

Revised February 1949

Scope

This list covers electric furnace or openhearth bars, billets or blooms.

Permissible Chemical Variations

Phosphorus and sulphur in openhearth steel to be 0.040% max. each, except in 8641 H.

Phosphorus and sulphur in electric furnace steel to be 0.025% max. each, except in 8641 H.

Small quantities of certain elements may be found in alloy steel which are not specified or required. These elements are to be considered as incidental and acceptable to the following maximum amounts: Copper 0.35%, nickel 0.25%, chromium 0.20%, molybdenum 0.06%.

The chemical ranges and limits shown are subject to the standard permissible variations for check analysis over the maximum limit or under the minimum limit. These permissible variations for sections of 100 sq. in. or less are: 0.01 for carbon up to and including 0.30%, 0.02 for over 0.30%; 0.03 for manganese up to and including 0.90%, and 0.04 for over 0.90; 0.005 for either phosphorus or sulphur; 0.02 for silicon up to and including 0.35%, 0.05 for over 0.35%; 0.03 for nickel up to and including 1.00%, 0.05 for nickel over 1.00 up to and including 2.00%, and 0.07 over 2.00%; 0.03 for chromium up to 0.90% inclusive, and 0.05 for chromium over 0.90%; 0.01 for molybdenum up to 0.20% inclusive, 0.02 for molybdenum over 0.20%.

General Notes

These compositions apply to steels produced to tentative hardenability bands (Data Sheets 19 to 24), determined by the standard end-quench on 1-in. round bars (Data Sheet 55), and to steels manufactured to "fine-grained steel practice".

Hardenability of steels may be specified in several ways: *(a)* Max. and min. distances on Jominy bar for any desired hardness; *(b)* Max. and min. hardness at any specified distance; *(c)* Two max. hardness values at two desired distances; *(d)* Two min. hardness values at two desired distances; *(e)* Any point on min. hardenability curve plus any point on max. curve. In addition to any of the above, the hardness limits at 1/16 in. may be specified.

Quality Conditions — All conditions and quality features, except as detailed above, shall be in accordance with the regulation, shown in the American Iron and Steel Institute's "Steel Products Manual", Section 10 on Alloy Steels.

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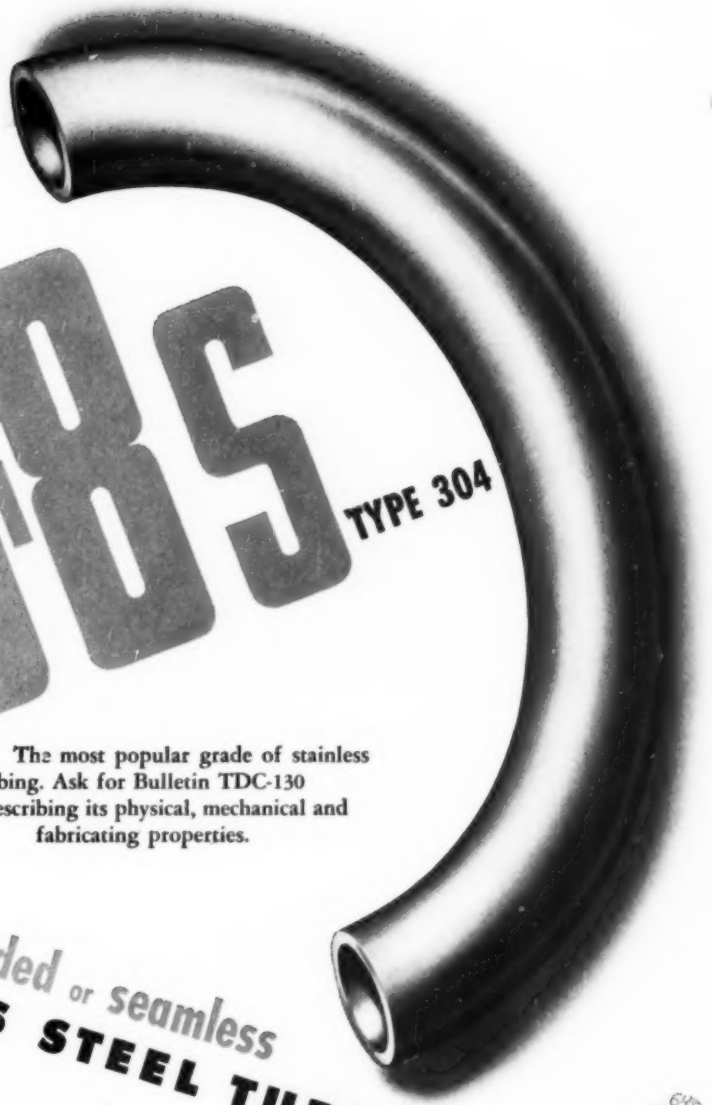

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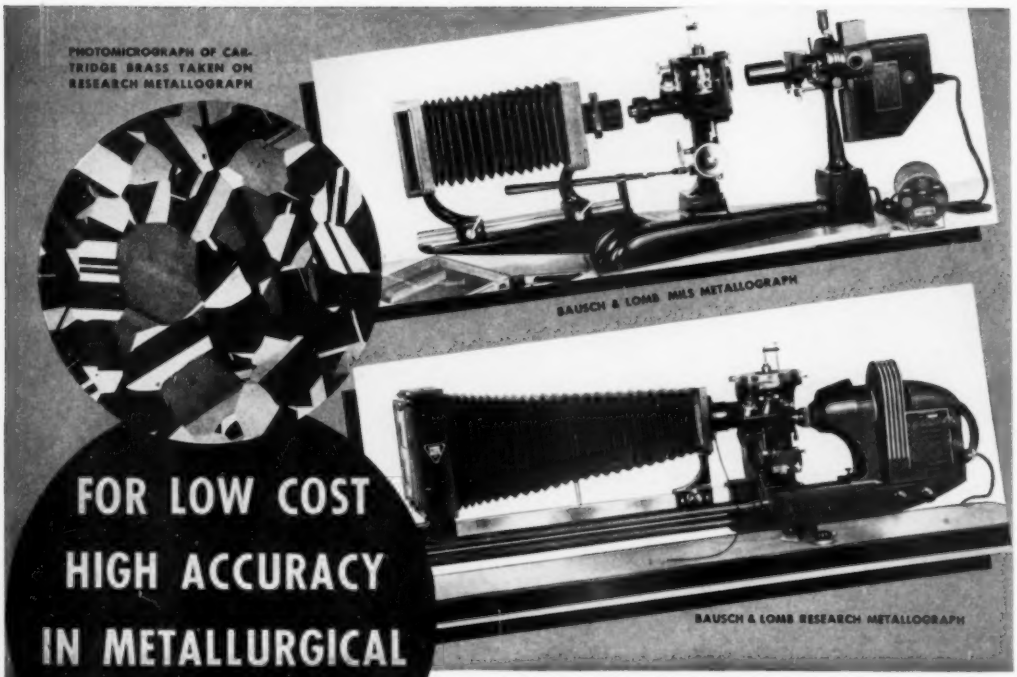
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TITANIUM

The industrial metallurgy of titanium is just beginning. It was encouraged recently through a Symposium on Titanium sponsored by the Office of Naval Research, with Government agencies, research laboratories and industry participating. Most of the information published here was presented at the O.N.R. symposium.

Titanium is much more abundant in the crust of the earth than copper, nickel, lead, tin, and zinc combined. Furthermore, titanium ores can be concentrated by well-established methods, and in 1946 nearly half a million tons of these concentrates were produced (mostly for pigments). Unfortunately, the metallurgy of titanium is difficult and expensive: The cost of producing ductile metal from ore is about 200 times the cost of the ore.

Metallurgists of the Federal Bureau of Mines deserve high praise for their initiative and success in developing methods for producing and fabricating titanium, but it still remains for industry to put the metallurgy on a tonnage basis and to get the cost of the metal down from its present high level of $5 a pound. These problems are worth the best efforts of industrial metallurgists, for titanium has three outstanding properties that will make it useful as a structural metal — high strength, light weight and excellent resistance to corrosion. A brief tabulation of properties is given below; detailed data will be published in another series of articles next month.

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PRODUCTION AND FABRICATION

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Induction Melting and Casting of Titanium Alloys 196
Arc Melting of Titanium 197
Spot Welding of Titanium 200

Comparison of Some Physical and Mechanical Properties of High-Purity Metals*

Metal	Melting Point	Thermal Expansion per °F.	Young's Modulus, Psi.	Density, G. per Cu.Cm.	Tensile Strength (Maximum Cold Work)	Ratio of Tensile Strength to Density
Titanium	3150° F.	4.7×10^{-6}	16×10^{6}	4.51	130,000 psi.	28,800
Iron	2800	6.5	29	7.87	100,000	12,700
Nickel	2650	7.4	30	8.90	115,000	12,900
Copper	1980	9.2	16	8.96	75,000	8,400
Aluminum	1220	13.3	10	2.70	20,000	7,400
Magnesium	1200	14	6.5	1.74	35,000	20,000

*Lack of data concerning titanium alloys precludes comparison on the basis of alloys.

The Titanium Program of the Navy Bureau of Aeronautics

By N. E. Promisel
Head, Materials Branch
Bureau of Aeronautics
U. S. Navy Department
Washington

THE BUREAU OF AERONAUTICS has been interested in titanium for almost three years. Information available in 1946 indicated that titanium might be useful as a structural material in aircraft and, as more data have been accumulated, the range of potential usefulness has expanded. Some of the most probable applications of titanium in aircraft are the following:

1. Substitution for aluminum alloys, magnesium alloys and steel, because of the high ratio of strength to weight for titanium at normal temperatures.

2. Substitution for stainless steel and light alloys, because of the outstanding resistance of titanium to corrosion by chloride and other environments. The protection of leading edges in high-speed aircraft illustrates the possible substitution of titanium for light alloys: At speeds approaching the speed of sound, the customary organic protective coatings on light alloys are abraded away by the impingement of dust, rain, and other particles in a few hours or minutes. Unless improved coatings or materials are devised for these leading edges, the efficiency of the airplane will decrease because of surface roughening and consequent increased turbulence and drag.

3. Substitution for steel where space is at a premium. The use of thin wings in supersonic aircraft, and the greater amount of space needed for the more numerous specialized equipments being carried, necessitate the use of materials that occupy a smaller volume than aluminum or magnesium but have the same load-carrying ability. Currently, steel is being used, even though it adds weight.

4. Applications involving temperatures of a few hundred degrees Fahrenheit, which are becoming more common in aircraft as a result of aerodynamic heating at higher speeds, the use of heat in de-icing, proximity of structural parts to hot installations such as jets and afterburners, higher temperatures in the compressors of turbines and jets, and other causes. The present high-strength light alloys begin to weaken seriously between 300 and 400° F. Although steels are readily available for use at these temperatures, the weight penalty is severe.

5. Superior titanium alloys may be developed for use at very high temperatures. For instance, studies by this bureau's contractor, P. R. Mallory & Co., show that the oxidation of titanium at about 1500° F. is retarded markedly by a few per cent aluminum or 1% silicon.

6. Finally, there are special applications such as high-speed hot air heater wheels, armor plate, and electrical components.

With so wide a range of potential uses, it is difficult to be specific about the properties desired in titanium and titanium alloys for military aircraft. However, titanium alloys having the following approximate properties could be used rather extensively: tensile strength, 135,000 psi.; tensile and compressive yield strengths, 110,000 psi.; elongation in 2 in., 10%; impact strength, 10 or 15 ft-lb.; modulus, 16 million psi.; and specific gravity, 4.5. At about 500° F., the strength should not decrease more than 10%, preferably when the metal is under stress for 1000 hr. Fatigue strength should be no less than one third the static strength. Not all these properties would be necessary in one alloy simultaneously. Current laboratory work indicates that these values are likely to be attained in titanium alloys.

The program of the Bureau of Aeronautics for achieving some of the objectives mentioned above includes:

1. Studies at the Naval Air Experimental Station in Philadelphia on metallurgy, fabrication and design, using titanium of commercial purity. One specific objective is the construction of several seaplane floats.

2. Corrosion studies at the above laboratory and at the Bureau's exposure sites near Norfolk, Va. Aside from showing the excellent corrosion resistance to chlorides, preliminary results indicate that contact of titanium with cadmium, cadmium-tin and zinc coatings does not accelerate the corrosion of titanium or of the coatings.

3. Development and evaluation of titanium alloys, and of methods for producing them. This work is being done under a contract with P. R. Mallory & Co. and also in collaboration with the Bureau of Mines. [Some details of these programs will be described in the next issue of *Metal Progress*.]

4. Investigations of special problems such as the high-speed heater wheel already mentioned, fire-walls in aircraft, and high-strength cable.

The Titanium Program of Army Ordnance*

By L. S. Foster
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ARMY ORDNANCE began to investigate titanium early in 1946, when samples of cast titanium were supplied us by Metal Hydrides, Inc. These samples had been produced from titanium powder obtained from the decomposition of titanium hydride, TiH_2. The hydride had been made from pigment-grade titania, TiO_2, by reaction with calcium hydride, CaH_2, and leaching with dilute acetic acid. The castings were brittle but it could be assumed that the brittleness resulted from accidental impurities which might be avoided by using better melting techniques. The chief disadvantage of the hydride titanium seemed to be the high price.

While the characteristics of hydride titanium were being considered, the Bureau of Mines developments were published and, for further experimental work, the Ordnance Department has used titanium produced by the Kroll process (reduction of titanium chloride by magnesium) rather than that obtained by the hydride method. However, additional work should be undertaken to assess the economic advantages of the various production processes. Until titanium can compete in price with other metals of high strength-weight ratio it will not be used widely for structural purposes except where its special properties dictate its adoption, regardless of cost.

To evaluate the potentialities of titanium as a structural material, the Ordnance Department is contributing to the support of work on titanium alloy systems in progress at the College Park Station of the Bureau of Mines. Believing that satisfactory heat treatments for titanium alloys can be worked out only if more accurate phase diagrams are available, the Ordnance Department has engaged Prof. John P. Nielsen and his group at New York University to study the titanium-carbon and titanium-nitrogen systems.

Watertown Arsenal has also initiated projects on titanium in its own laboratories. These projects include studies of mechanical properties at high and low temperature, resistance to shock, ballistic properties, and welding characteristics. Other investigations are concerned with the physical metallurgy of titanium alloys, such as titanium-iron alloys, to determine how the mechanical properties are affected by microstructure, temperature and composition.

To visualize the potentialities of titanium alloys having a high ratio of strength to weight, one merely needs to remember that future armies and their equipment must be transportable by air. Only the high cost of titanium and the lack of detailed information about the properties of titanium alloys prevent the large-scale adoption of this metal in ordnance.

*The opinions expressed in this paper are those of the author and do not necessarily express the views of the Ordnance Department.

The Titanium Program of the Air Materiel Command

By Richard R. Kennedy
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THE AIR MATERIEL COMMAND has three projects on titanium at the present time. One of these is a contract with the Battelle Memorial Institute; the work will be described in other articles of this series, by members of the Battelle staff.

A second project is a contract with the Ohio State University Research Foundation. [This work will be described by D. G. McPherson and M. G. Fontana in the next issue of *Metal Progress*.]

The third project will be carried out by the Materials Laboratory to determine the properties of commercial titanium, with a few tests on higher-purity titanium produced from titanium iodide. We have already determined some of the expansion characteristics of titanium, using the dilatometer. Tension, compression, fatigue and stress-corrosion tests will be conducted on commercial titanium sheet, both annealed and cold rolled. Tension tests will be performed at subzero and elevated temperatures. The solution potential will be determined, and corrosion tests will be run on titanium coupled to other aircraft structural metals.

The Titanium Program of the Naval Research Laboratory

By E. J. Chapin
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IN THE METALLURGY DIVISION of the Naval Research Laboratory we are seeking to develop useful high-strength titanium alloys. Our specific aims include the following:

1. To discover satisfactory procedures for the induction and arc melting of titanium.
2. To determine the equilibrium relations in the titanium-oxygen system.
3. To determine methods of fabrication and physical, mechanical and chemical properties of titanium alloys produced by melting and casting.
4. To construct equilibrium diagrams of the more promising alloy systems involving titanium.

Most titanium thus far has been consolidated by pressing and sintering. These techniques of powder metallurgy are not well suited to the production of large shapes; it would be better to cast the metal and then to fabricate it by forging and rolling. Therefore, we are trying to develop satisfactory methods for melting and casting titanium. The first necessity is for a crucible that will not react with molten titanium, for such reaction will cause the solidified casting to be brittle. We are studying the suitability of graphite, carbon, beryllia, thoria, stable carbides and borides, and other pure refractories. No entirely satisfactory crucible material has been found yet.

Because titanium readily absorbs oxygen, nitrogen and hydrogen at elevated temperatures the metal must be melted in a vacuum or in purified argon or helium. Serious problems are involved in the construction of melting equipment that will maintain a high vacuum at high temperature. Too much space would be required to describe the vacuum techniques that are required. It must suffice here to say that we have built an induction furnace (capacity, 3 lb.) which will operate satisfactorily at a vacuum of 0.001μ Hg up to 4000° F.

It is very difficult to produce commercial titanium free from oxygen. Therefore, the relationship between oxygen content and mechanical properties is of great practical importance. A proper evaluation of other titanium alloy systems can be made only after the effects of small amounts of oxygen on the properties of pure titanium are known; hence our decision to study the effect of oxygen on the structure and properties of titanium.

Facilities have been assembled for producing high-purity titanium by the iodide process. This metal will be the base of our titanium-oxygen alloys. Measurement of the amount of oxygen in titanium is itself a difficult problem. Apparatus for vacuum fusion analysis has been built and the method is being investigated.

Production of Titanium Powder by the Bureau of Mines

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THE METALLURGICAL DIVISION of the Federal Bureau of Mines has been investigating the production and technology of titanium for several years. That part of the work done at the Boulder City station under the general direction of C. W. Davis has as its principal objective the production of ductile titanium. Nearly all impurities in titanium decrease the ductility, but nitrogen, oxygen and hydrogen embrittle the metal much more than other elements. In fact, ductile titanium can be defined as titanium with a minimum of dissolved gases. Titanium embrittled by hydrogen may be made ductile by heating in a vacuum, but no method is known for restoring the ductility of titanium embrittled by oxygen or nitrogen. Therefore, if it is to be ductile, titanium must be produced in an environment substantially free from oxygen and nitrogen.

After a survey of all known methods of making titanium, the Bureau of Mines selected the Kroll process for further experimentation and development, because it seemed more easily adapted to large-scale work than any of the other processes capable of producing metal of the requisite purity. In the Kroll process, titanic chloride is reduced with magnesium in a closed

iron chamber between 1475 and 1650° F. Helium at a positive pressure of ½ to 1 lb. is maintained in the reaction chamber while it is hot, in order to protect the contents from oxidation.

The principal products of the reaction are molten magnesium chloride and solid, spongy titanium metal; some unused magnesium remains at the end of the reaction. If the supply of magnesium becomes depleted or inaccessible to contact with the titanic chloride for any reason, the titanic chloride may react with titanium already formed to yield titanous chloride, or with the iron walls of the reaction chamber to yield ferrous chloride. These side reactions may be minimized if the amount of titanic chloride in the charge is only 90% of the amount theoretically necessary to combine with the magnesium present, and if the temperature is between 1475 and 1650° F.

Titanium metal in relatively pure form may be recovered by either of two methods from the solid mixture of titanium sponge, magnesium chloride, and unused magnesium after the reaction has been completed and the chamber has cooled. The method used for most of the production work at Boulder City involves mounting the open reaction chamber in a large lathe and boring out the reaction product. The chips so formed are first leached with dilute hydrochloric acid to remove most of the magnesium chloride and unused magnesium, then ground wet in a ball mill operating in closed circuit with a shaking screen. The ground metal is then leached again in strong hydrochloric acid, washed, dried, rescreened, and separated magnetically to give finished powder.

In the second method of purification, used at Boulder City only for small experimental batches, the opened reaction chamber and the reaction product are heated in a vacuum retort. Most of the magnesium chloride and unused magnesium either evaporates or melts and drains off.

In the course of our investigations, the scale of operation has been increased many times. The first reduction chambers were only about 2 in. in diameter by 3 in. high and made only a few grams of titanium. No significant trend was noted in yield or quality of metal as the scale of operation was increased gradually to 130 lb. per batch.

In the various increases in scale, the reaction chamber has kept much the same form — a vertical cylinder of mild steel somewhat greater in height than diameter, and with a flat bottom and top. A vertical feed pipe, long enough to extend through the lid of the furnace used to heat the pot, and having a diameter about one fifth that of the pot, was attached at the center of the lid.

When the scale of operation was increased from 130 to 220 lb., serious difficulty was encountered. Increasing the size of the pot altered the heat transfer characteristics in such a way that the heat of reaction could not be dissipated fast enough to prevent a steadily increasing temperature in the reaction chamber, until the magnesium began to boil. Then the zone of reaction was shifted from the surface of the magnesium bath to the point where the magnesium vapor and titanium chloride met at the end of the feed pipe. The heat of reaction, developed close to the lid, caused the metallic titanium to react with the lid to form the low-melting iron-titanium eutectic, which dripped down into the reaction mass.

The reaction could be controlled simply by slowing down the rate of feed, but this was unsatisfactory because it spread the time for the reduction over two shifts, thus virtually doubling the labor cost for that particular step of the process. Two other methods were found for controlling the excess heat. One was to use as slow a feed as would complete the run in one shift and to add part of the magnesium as solid ingots during the run, so that, in melting, the magnesium ingots absorbed some of the heat liberated by the reaction. The other method was to use the minimum feed rate consistent with single-shift operation and to have a rotating discharge on the titanic chloride feed pipe, so that the zone of reaction was spread out over a larger area and the heat generated did not have to travel so far in getting to the walls.

Feeding the titanic chloride through a rotating discharge was found easier in practice, but it had one disadvantage. A solid impermeable layer of titanium formed across the top of the bath, and a long bar had to be inserted into the chamber to break this crust and allow the reduction to proceed satisfactorily. Entrance of air into the pot during this operation was prevented by maintaining a strong outward flow of helium while the pot was open. This technique has apparently solved the difficulties encountered in operating with 220-lb. batches, but in any further increase in the size of batch, the problem of heat dissipation will require careful consideration.

Impurities

The principal impurities in the titanium produced at Boulder City are magnesium, chlorine, iron, manganese, hydrogen and oxygen.

Magnesium and chlorine result from the inclusion of magnesium chloride and metallic magnesium in the sponge during reduction. The magnesium content of the finished (leached) powder is between 0.4 and 0.5% and the content of chlorine is from 0.1 to 0.15%. The magnesium content of the sponge produced by vacuum puri-

fication of the reaction product is somewhat lower, but the chlorine content is about the same.

The magnesium content may be decreased to 0.05% by heating the standard powder in a vacuum for 16 hr. at 1830° F. The powder should be packed loosely in layers not thicker than 2 in. The magnesium content of thin pressed compacts may also be decreased by vacuum sintering, for instance, from 0.5% to less than 0.1%. The magnesium in titanium powder is almost completely volatilized by fusion, so that cast ingots contain only a trace of magnesium. The chlorine is affected little at any temperature up to 1830° F., but is removed almost completely by fusion.

Iron comes from the steel reaction chambers, and may enter the titanium either by direct contact along the walls of the pot or by reduction of volatile iron chloride formed by reaction between hot iron and titanic chloride. Small amounts of iron may also be picked up from the iron balls used in grinding and from the magnesium.

The iron content of titanium is not decreased by heating in a vacuum, either to the sintering temperature or to actual fusion. However, the iron content can be controlled during reduction and processing. During the reduction, high temperatures and high utilization of magnesium give a product with higher iron content. During the turning of the reaction product to make chips for leaching, high-iron and low-iron fractions may be obtained by segregating the chips from near the walls of the reaction chamber. Leaching reduces the iron content of the product, and this may be accentuated by prolonging the time of leaching, by leaching at a higher temperature, or by adding a small amount of sodium fluoride to the leaching acid. In both the second and third techniques, the operator must be careful to prevent an uncontrollable increase in the temperature, a violently boiling bath, and a ruined batch of powder. A high leaching temperature or the addition of fluoride to the acid also causes an increase in the hydrogen content of the powder, and adding fluorides causes an undesirable increase in the corrosion of the container. Therefore, the time of leaching, rather than the temperature or fluoride content, has been increased; the ground and sized powder is leached again, for 20 hr. at 65° F.

With careful operation, the average iron content will be less than 0.1%. Under certain favorable conditions that are not yet fully understood, iron contents as low as 0.04% may be obtained.

The small-scale work indicates that it will be more difficult to control the iron content with vacuum purification, as this procedure allows no opportunity to decrease iron content by leaching. Some vacuum-distilled sponge contained 0.22% Fe.

Manganese gets into the charge as an impurity in the magnesium, which usually contains nearly 0.1% manganese. The manganese content of titanium is affected little by vacuum sintering or leaching and is reduced only slightly by vacuum fusion. Some control of the manganese content of the powder is possible by segregation, because the first titanium formed is much higher in manganese than the metal formed later. However, this method has the disadvantage that for every pound of powder low in manganese, there will be an equivalent amount high in manganese.

The most satisfactory method of control is to use magnesium that contains no manganese. Magnesium can be produced free from manganese at no additional cost if there is a sufficient demand. For experimental work, some magnesium has been purchased that contains less than 0.01% manganese; from this, it will be possible to produce titanium low in manganese.

Hydrogen is adsorbed by the titanium powder during leaching. The amount present depends on several variables: It will vary with the amount of magnesium that remains unused after the reaction, with the temperature during leaching, and with the amount of titanium dissolved during leaching. The hydrogen content of the powder will normally be about 0.1% by weight or 11 ml. per g. of titanium, but under some conditions of leaching the value may be much higher.

By heating the powder for a few hours at 1475° F. the hydrogen content may be decreased to a few thousandths weight per cent. This may seem like a small amount, but it is equivalent to one volume of hydrogen per volume of metal, and is sometimes enough to cause difficulty.

Oxygen is the most important of all impurities in its effect on the mechanical properties of titanium. Unfortunately, there is no reliable method for estimating the oxygen content of titanium. Various considerations lead us to believe that it ranges between 0.05 and 0.1% by weight. A study of various methods of analysis is now under way.

Because of the spongy nature of the titanium formed by the reduction, it seems likely that some moisture and hydrated magnesium compounds will be retained in the pore structure after leaching and thereby increase the oxygen content of the metal. For this reason, titanium sponge produced by vacuum purification and never exposed to aqueous solutions probably has a lower oxygen content than titanium powder that has been leached. Equipment for the production of substantial amounts of vacuum-purified sponge will be installed in the near future in an attempt to provide titanium having a lower oxygen content.

The Consolidation of Titanium Powder by Sheath Rolling

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TITANIUM POWDER is usually consolidated by pressing and sintering, but high pressures are required, and the sintering must be done in a vacuum or an inert atmosphere. Furthermore, the standard procedures of powder metallurgy are not suited to the production of large pieces. The new method described here consists of sealing the titanium powder in metal containers and rolling the assembly at elevated temperature. We call this "sheath rolling".

Sheath rolling permits the fabrication of an almost unlimited mass of metal into a single piece. Sheath rolled titanium is dense and sound, in contrast with the porous compact obtained by pressing and sintering, as illustrated in Fig. 1. Like the standard metal, sheath rolled titanium is ductile and can be further cold worked; it is equivalent in structure to sintered titanium that has been worked and annealed. Some mechanical properties of titanium produced by both methods are given in Table I.

Common hot rolled steel sheet or pipe has been used satisfactorily for the containers or sheaths that protect the titanium powder and confine it during working. Protection from active gases is necessary because both oxygen and nitrogen react rapidly with titanium at the working temperatures and diffuse into the solid metal, causing excessive hardening and embrittlement. The confining action of the sheath is likewise essential; it permits distortion of the individual particles of the powder, which will rupture any surface films that may be present and thus will produce good contact between the powder particles, permitting diffusion and welding into a dense coherent mass. The sheaths can be removed readily from the finished metal. A thin, brittle iron-titanium alloy layer formed at the contact surfaces probably makes this easy stripping possible. Contamination of the titanium surface by iron is slight and can be removed easily by pickling.

Compacts were usually worked at 1650° F., although temperatures ranging from 1475 to 1825° F. were used also. At 1825° F., excessive oxidation of the sheath may cause roughness of the titanium surfaces because of rolled-in scale. Also, the sheath walls may be oxidized completely

Fig. 1 — (Left) Titanium Consolidated by Sheath Rolling and (Right) Titanium Bonded by Standard Powder Methods of Pressing and Sintering. × *125*

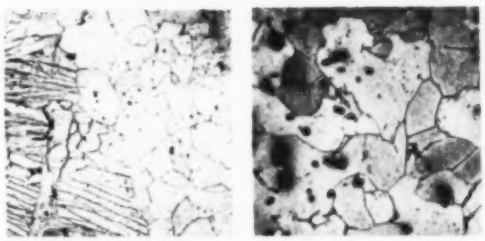


Table I — Some Mechanical Properties of Standard Titanium Sheet Produced by Pressing and Sintering and Sheet Produced by Sheath Rolling

Condition	Tensile Strength, Psi.	Yield Strength (0.2% Offset), Psi.	Proportional Limit (0.01% Offset), Psi.	Elongation, % in 2 In.	Hardness, Rockwell G
1. Green compacts sheath rolled at 1475° F.	97,600	75,000	58,000	15.1	81
2. Standard compacts sintered, cold rolled, and annealed at 1475° F.	79,100	64,000	58,800	24.7	76
3. Same as 1, plus 40% cold reduction	129,400	111,500	75,600	2.6	94
4. Same as 2, plus 40% cold reduction	122,200	113,300	84,400	7.5	91

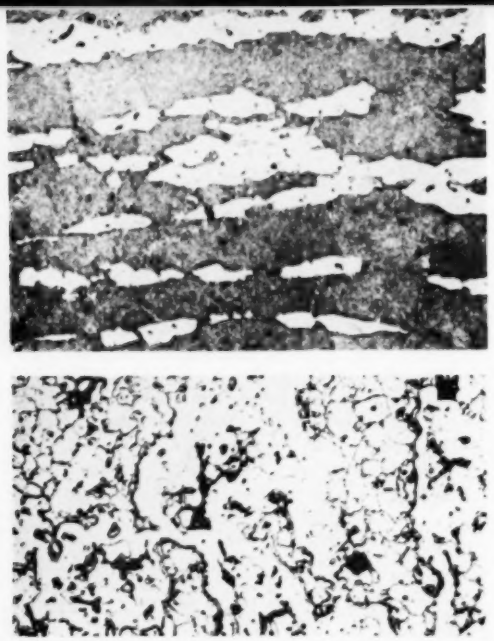


Fig. 2 — Alloy Containing 75% Titanium and 25% Copper. (Top) As consolidated by sheath rolling. (Bottom) As sintered. Both × 250

through when thin sections are rolled at this temperature. At still higher temperatures (1920 to 2000° F.) the surface layer of iron-titanium alloy will melt. Consolidation by sheath rolling below 1475° F. is not satisfactory because of the low diffusion rates, as indicated by slow recrystallization and grain growth at these temperatures.

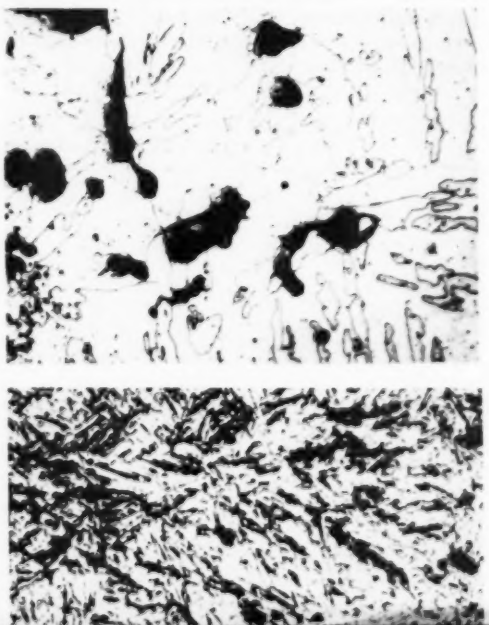
The loose titanium powder has a volume three to four times that of the consolidated metal; therefore, maximum utilization of the volume of the sheath requires tightly packed powder. This may be accomplished by pressing the powder directly into the container, or by forming pressed compacts and inserting them into a closely fitting sheath, as was usually done in this work. Another important factor is the residual gas sealed in with the metal. The air should either be replaced by an inert gas before the final sealing, or its volume should be reduced to a negligible amount by the use of a closely fitting sheath to give a large ratio of metal to residual air. The hydrogen normally present in titanium powder will embrittle the metal unless it is removed before the metal is consolidated. Hydrogen is removed readily by pumping it out between 1300 and 1475° F.

Pressed but unsintered compacts — as well as loose powder — can be consolidated into a single piece of metal by sheath rolling. This was demonstrated with two compacts placed side by side and two compacts placed one on top of the other in the sheaths. Each of these compacts was completely welded during rolling, and no evidence of the original interface between the blocks could be found on microscopic examination. Large masses of solid, ductile titanium can be prepared readily by sealing any number of small pressed blocks in a container of suitable size and hot rolling the assembly. The small blocks, like the individual titanium particles, will weld together, giving a solid piece of titanium with no indication of the original contact faces.

Alloys of titanium with other metals also have been prepared by sheath rolling the mixed powders at appropriate temperatures. Dense homogeneous alloys can be formed in this manner, with much less trouble than is encountered in normal pressing and sintering. Examples of the microstructures of alloys prepared by sheath rolling and by normal pressing and sintering are given in Fig. 2 and 3. These structures emphasize the advantages obtained by the sheath rolling methods.

Although the new method of consolidation was developed for titanium, it has a wide range of application to other metal powders or fragments. Chromium, tantalum, tungsten, molybdenum, beryllium, cobalt, iron, nickel, and copper powders have been consolidated successfully by sheath rolling, as have large metallic fragments such as zirconium scrap turnings and electrolytic cathode chips of chromium, cobalt and manganese.

Fig. 3 — Titanium Containing 2% Iron. (Top) Sintered, reheated 4 hr. at 1650° F., quenched. (Bottom) Sheath rolled at 1650° F., quenched. × 250



The Production of Titanium by the Iodide Process

By Bruce W. Gonser
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Columbus, Ohio

THE THERMAL DECOMPOSITION of a volatilized titanium iodide is the most practical way of obtaining high-purity titanium in a compact form that can be processed directly, without melting or pressing and sintering.

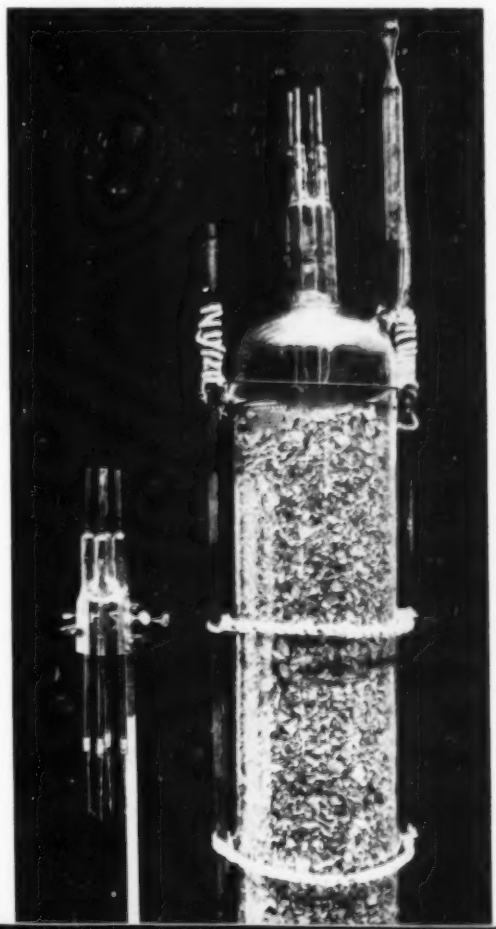
The iodide process was first described by Van Arkel and de Boer in 1925; several technical articles by these investigators and by J. D. Fast in the following 14 years gave additional information about the process and the deposited product. In subsequent commercial development of the iodide process by the N. V. Phillips Gloeilampenfabrieken in Eindhoven, Netherlands, emphasis was on the production of zirconium. However, enough work was done on titanium to outline some of the conditions and equipment necessary for deposition.

The process depends on the formation of a volatile titanium iodide by reacting crude titanium with iodine in the absence of any other reactive gas, then depositing the titanium on a hot filament by thermal decomposition of the iodide. This action is cyclic — the gaseous product of decomposition reacts with more crude metal.

The reactions depend on the temperature at which the crude metal is held. Thus, with metal held between room temperature and 480° F., iodine reacts with the crude metal to form TiI_4, which dissociates at the hot filament: $TiI_4 \rightleftarrows Ti + 2I_2$. At a higher temperature, however, the tetra-iodide reacts with more metal to form TiI_2, which has a much lower vapor pressure than the tetra-iodide; hence, virtually no metal deposits until the temperature of the charge is increased above 800° F. For either process, the temperature of the filament is between 2000 and 2730° F.

Some idea of the equipment used for making iodide titanium may be gained from the tubes designed by the Phillips Co. As duplicated at Battelle Memorial Institute, in a project for the Foote Mineral Co., a Pyrex glass tube about 20 in. long and 4 in. in diameter was used. This was equipped with a glass head containing three sealed-in tungsten rods for electrodes, to which were attached tungsten filaments arranged so that if one filament burned out, the run could be continued on the remaining two. A side arm contained the iodine supply which was refrigerated to prevent loss while the tube was being evacuated and sealed. The charge of crude metal lumps, formed by reduction of titanium oxide with sodium or calcium, was held in place around the periphery of the tube by a screen of woven molybdenum wire. Two rods of metal about 15 in. long and ¼ in. in diameter could be produced in each run.

Current Production Equipment and Product — The production of iodide titanium in glass equipment is handicapped severely by the weakness of glass at high temperature, its fragility, and the difficulty of sealing-in electrodes large enough to permit the building of heavy deposits. To a surprising extent, success depends on the glass blower who makes, opens, and repairs the tubes. However, production units for titanium have been increased in size to glass tubes 35 in. long and 7½ in. in diameter, as shown in the illustration below.



Each tube can produce two 24-in. "hairpins" (300 g. each) per run at 330° F. The construction and operation of these glass tubes have been described previously by I. E. Campbell, R. I. Jaffee, J. M. Blocher, J. Gurland and B. W. Gonser (*Transactions* of the Electrochemical Society, V. 93, June 1948, p. 271 to 285).

Such units have been operated successfully either at 330 or 1020° F. Operating at the lower temperature has some obvious advantages, but the purity of the product (as indicated by hardness) has not been so satisfactory as when produced at 1020° F. Consequently, the process has been run at the highest temperature that the glass equipment can withstand safely.

Control is largely a matter of dissipating energy, rather than supplying heat, since little energy is consumed in the refining reactions. As the deposit builds on the starting filament, more and more current is required to maintain the filament temperature, until the dissipation of heat becomes a major problem. This is particularly true with large glass equipment, because the danger of cracking or collapse makes undesirable the use of a molten cooling bath around the tube.

To avoid some of the disadvantages of glass, metal reaction tubes have been built. One currently in production is 30 in. long and 4¼ in. in diameter, giving one double rod or "hairpin", 24 in. long, as shown in the next column. Rods ⅝ in. in diameter and weighing from 700 to 750 g. have been produced in this metal equipment. Operation is so simple and satisfactory that we consider glass tubes obsolete except for experimental work. A temperature of 330° F. is maintained easily by immersing the metal tube in a bath of circulating oil during deposition. Quality of product has been entirely satisfactory, probably partly because the larger volume of metal dilutes any impurities deposited at the start of a run.

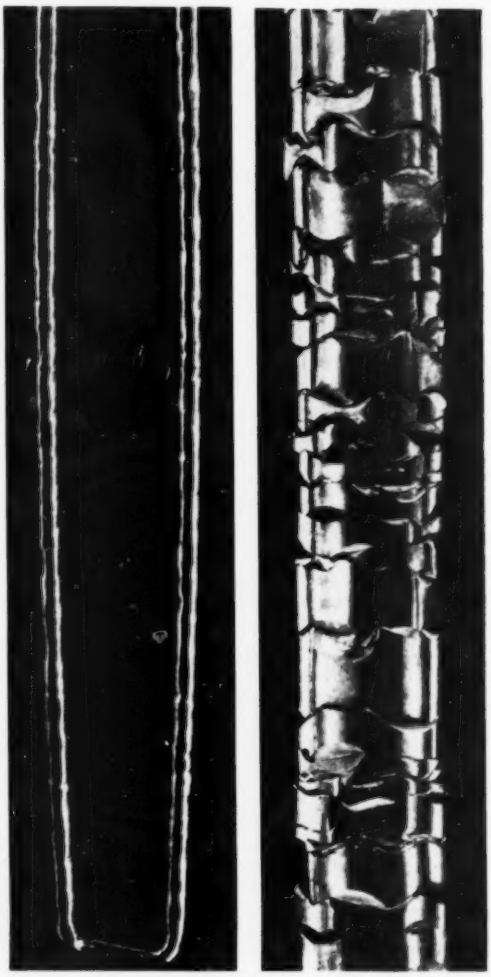
Operation — Between 12 and 15 lb. of fused lumps of crude metal is charged into the metal tube and about 20 lb. into each of the large glass tubes currently in use. This charge is held in a ½-in. space between the tube wall and a perforated screen made of sheet molybdenum. Several runs are made with a given charge, which is then washed thoroughly in water to avoid diminished activity. The same charge is thus used repeatedly.

Time for a run varies with conditions; usually 24 to 30 hr. is required for a high-temperature run in a glass tube to build a rod requiring up to 300 amp. to maintain filament temperature. A minimum of 10 hr. has been attained. With a metal bulb, in building a rod ⅝ in. in diameter requiring up to 580 amp. to maintain the temperature, from 30 to 48 hr. has been required.

Power consumption has been as low as 40 kw-hr. per pound of metal deposited, but is usually 60 to 75 kw-hr. Continued development of the iodide process may make it fully competitive with other methods for producing titanium commercially.

[The composition, structure and properties of iodide titanium will be discussed in two articles to be published in next month's *Metal Progress*.]

(Left) A "Hairpin" of Iodide Titanium, ⅝-In. Diameter; (Right) Close-up of Iodide Titanium Deposited From a Low-Temperature Charge.



Induction Melting of Titanium in Graphite

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E. I. du Pont de Nemours & Co.
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THE MELTING AND CASTING of titanium present many difficult problems. The metal has a high melting point (about 3150° F.) and, when molten, reacts with virtually everything it touches. All oxide refractories are reduced by molten titanium, which is then contaminated and embrittled by both the oxygen and the metallic elements.

W. J. Kroll (*Metals Technology*, February 1946) reported melting titanium on a small scale in a controlled atmosphere by a special arc-melting procedure that did not permit the molten metal to come in contact with anything but titanium powder. In a later publication (*Metals Technology*, January 1948), Kroll, Anderson and Gilbert described the use of a graphite-resistor vacuum furnace for melting zirconium and mentioned its use in melting titanium. Although some carbon was picked up by the metal during melting, the hardness was not affected appreciably.

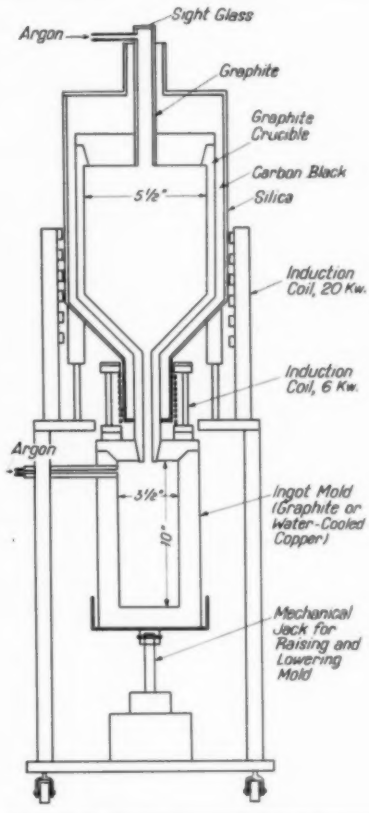
About a year ago, we started development work on the induction melting of titanium in graphite. A 10-lb. ingot scale was selected for the first work and, to simplify subsequent increase to 100-lb. and larger sizes, melting and casting were done in an atmosphere of argon instead of in a vacuum. At first, crucibles were made of the purest grades of graphite, but difficulties with flow of the molten metal through pores in the graphite soon led to replacement with denser, less pure forms. National Carbon graphite (grade CS), baked at 3650° F., has been used successfully.

Equipment for producing 10-lb. ingots is shown in the accompanying diagram. High-frequency power is supplied to the two coils from 20-kw. and 6-kw. Ajax spark-gap converters.

In charging the crucible for a 10-lb. melt, the opening at the bottom of the crucible is closed with a piece of titanium sponge, and 10 lb. of crushed sponge particles from ¼ to 3 in. in size is then added. The bulking density of the sponge is about 1.0. The charge is heated from room temperature to 1100° F. in 1 hr. with about 6-kw. input to the 20-kw. spark-gap converter. The power is then increased to 18 or 20 kw. and the charge is melted in about 30 min. The small coil around the pipe between the crucible and the mold is turned on at this time, and 1 to 3 min. later the molten metal flows into the mold.

The ingots obtained by this procedure contain from 0.4 to 0.7% carbon and 99.0% titanium; the remainder is minor impurities present in the 99.5% titanium sponge used in the charge. As cast, the ingots vary in hardness from slightly below 200 to 240 Vickers. They machine about like 18-8 stainless steel and can be forged readily to round or square bars between 1700 and 1900° F. Forged bars can be hot rolled between 1200 and 1600° F. with about 10% reduction in thickness per pass.

Facilities have been installed recently for melting and casting 100-lb. ingots by direct scale-up of the 10-lb. operation. Procedures are now being worked out for production of the large ingots.



Unit for Induction Melting and Casting 10-Lb. Ingots of Titanium. Supports for the silica container are fastened to a transite top on the main furnace supports.

Induction Melting and Casting of Titanium Alloys

By P. H. Brace
Consulting Metallurgist
Research Laboratories
Westinghouse Electric Corp.
East Pittsburgh, Pa.

OUR FIRST CONCERN in melting titanium was to find a suitable refractory. Ordinary silicate-bonded refractories were useless, and graphite was unsatisfactory for our purposes. In order to test the suitability of oxides, we melted small blocks of titanium in contact with compacted and sintered test pieces of several pure oxides, in a vacuum.* Molten titanium reacted exothermically with Al_2O_3 to produce a brittle alloy bearing no resemblance to titanium. BeO reacted less vigorously, but the resultant alloy was contaminated too much to be useful. With ThO_2, the reaction was slight and, after melting, the titanium was enough like the original metal to encourage the thought of using thoria crucibles.

Our first successful crucibles were made by plastering the inner surfaces of cylindrical molybdenum capsules with a paste made from ground, electrically-fused thorium oxide, plasticized with an acid-treated slip made by wet-grinding fused thorium oxide. After these crucibles were dried in air and baked at about 575° F., they were fired by inductively heating the molybdenum capsule in a vacuum at approximately 3600° F. for a few hours. Such crucibles were used for vacuum melting various titanium alloys and were fairly satisfactory, providing the metal was not heated too far above the melting point. Later, thoria crucibles were obtained from commercial sources. Some of these resisted attack quite well, but others soaked up the liquid titanium alloy as a blotter absorbs ink. Although we have successfully prepared about 60 titanium alloys in thoria crucibles, the refractories problem is not solved; the best of the crucibles were fairly satisfactory, but the worst were useless. The best results were obtained from a dense high-purity thorium oxide, fired at about 3600° F.

One purpose of our program was the casting of tensile specimens of various titanium alloys in a vacuum or a controlled atmosphere, using induction melting. A vacuum casing, approximately 30 in. in diameter and arranged to rotate about a horizontal axis, enclosed the inductor coil, melting

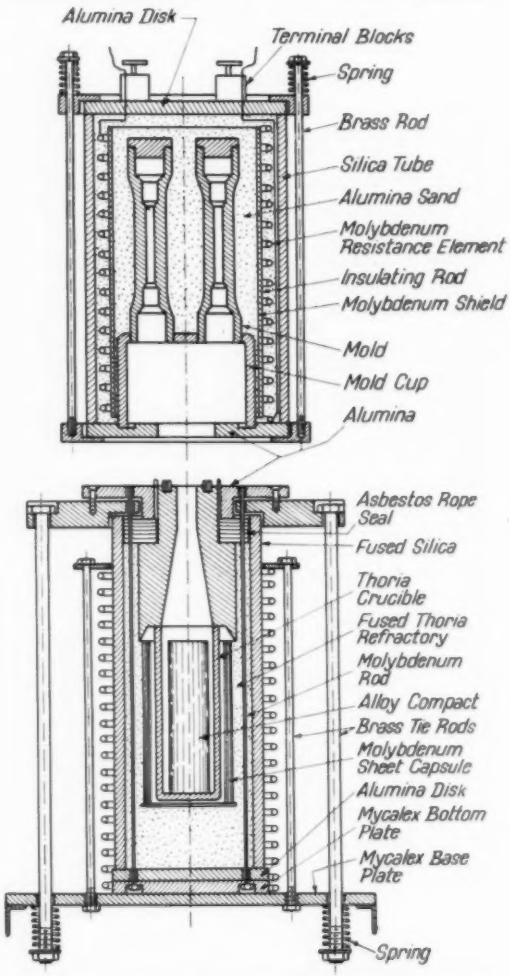


Fig. 1 — Crucible (bottom) and Mold (top) for the Production of Cast Tensile Specimens of Titanium Alloys. The metal is melted and cast in a vacuum or an inert atmosphere.

*EDITOR'S NOTE: These experiments have been described in detail by the author in "Reaction of Molten Titanium With Certain Refractory Oxides", *Transactions* of the Electrochemical Society, Vol. 94, October 1948, p. 170 to 176.

assembly and mold assembly. The exhaust system included a multiple-stage oil-vapor high-vacuum pump, an oil-vapor booster pump, and a two-stage mechanical fore-pump. With the vacuum casing clean and cold, a pressure less than 10^{-5} mm. Hg could be obtained. During melting and casting, the pressure was between 1 and 30 μ Hg.

Some metals, notably chromium, vaporized considerably during melting. Outgassing before melting, and casting under an atmosphere of purified argon at a pressure of a few millimeters of mercury prevented most of the vaporization without introducing enough gas to interfere with the flow of metal into the mold. We were able to prepare quite pure argon with only slight inconvenience. The purification system had two vertical stainless steel tubes connected at top and bottom so that the gas to be purified could circulate up one tube, which was heated, and down the other, unheated tube under the pressure difference between the hot and cold gases. In the hot tube, calcium metal chips combined with and removed any reactive gases in the argon. The argon was held under a pressure of about 50 psi., and the maximum temperature of the calcium was about 1300°F. After a fresh charge of commercial argon had "soaked" overnight it usually showed no detectable amounts of impurity, by analysis in the mass spectrograph.

The vacuum melting routine was: Assembling the components of the charge in the crucible, mounting the charged crucible in a silica tube, fixing them within the inductor coil, assembling the components of the mold, evacuating the melting chamber, outgassing the mold, preliminary heating and outgassing the charge, melting the charge, adjusting the temperature of the melt, and finally casting.

The mold assembly was heated by a molybdenum resistance wire wound on an alundum tube. The mold proper consisted of a pouring cup and either three or four mold cavities (in the shape of tensile specimens) machined from round bars of graphite or soft-bodied magnesia.

The mold was carried on an arm that could rotate about an axis parallel to that of the melting assembly. During melting, the mold was removed to one side, leaving a clear view of the interior of the melting chamber. Just before the metal was to be cast, the mold was swung over the furnace, as shown in Fig. 1. The mold was held with its opening over the pouring nozzle and bedded against an asbestos gasket that provided a metal-tight seal between the melting chamber and the mold inlet. The metal was then cast by rotating the whole arrangement 180°, which discharged the molten metal into the mold.

Arc Melting of Titanium

By O. W. Simmons, C. T. Greenidge and L. W. Eastwood
Battelle Memorial Institute
Columbus, Ohio

BECAUSE of the extreme chemical reactivity of molten titanium, no suitable refractory to contain it has yet been found. Furthermore, the molten titanium reacts very readily with oxygen, nitrogen, and moisture in normal atmospheres. For these reasons, conventional melting methods are not generally applicable to titanium. Primarily to overcome the problem of refractories, Battelle has adapted the arc furnace to the melting of titanium; during this operation, the titanium or its alloy is produced in ingot form preparatory to hot fabrication by conventional methods.

All of the arc furnaces built for the production of titanium ingots have been characterized by three main features as follows: *(a)* a water-cooled tungsten electrode, *(b)* a water-cooled copper crucible, and *(c)* provision for an inert argon atmosphere of high purity.

The original adaptation of the arc furnace to the melting of refractory alloys at Battelle was carried out by S. A. Herres and James A. Davis, under Project RAND,* and a description of their early developments is included in their unpublished paper "Arc Melting of Refractory Metals Such as Titanium and Their Alloys".† These earlier arc furnaces were quite useful in making a limited number of melts of refractory metals such as tungsten-molybdenum, chromium-molybdenum, and chromium-base, titanium-base or zirconium-base alloys. More recently, in connection with an extensive alloy development program sponsored by the Wright-Patterson Air Force Base, it became necessary to improve the arc-melting furnace designs to permit the efficient production of a large number of experimental alloy ingots. In that phase of the program, designed to improve the characteristics of the arc furnace used for

*Project RAND is being conducted under a U. S. Air Force Contract with the RAND Corporation, Santa Monica, California.

†EDITOR'S NOTE: A fairly complete summary of the early work by S. A. Herres and James A. Davis was included in the original paper submitted to the Titanium Symposium.

melting refractory alloys, emphasis was placed on the design of a furnace having 1-lb. capacity and one having 5-lb. capacity. The smaller size is employed for the exploratory work on alloy development, while the larger is employed in the production of promising compositions which merit more detailed investigation. During the same period covered by this development, Du Pont "Process A" titanium sponge crushed to sizes smaller than ½ in. has become available. This material is substantially free of gas and volatile constituents and, therefore, much less difficulty has been encountered with spattering, a serious difficulty experienced when melting the Bureau of Mines powder which contained large volumes of hydrogen.

Furnace of 1-Lb. Capacity — The design of this furnace is illustrated by Fig. 1 and, in addition to the three basic features listed above, the following were also incorporated:

1. A hemispherical crucible bottom or a flat-bottom crucible joined to the vertical walls by a generous radius in order to reduce the cooling area and minimize the heat loss from the ingot and at the same time to avoid the poor melting which would otherwise occur in the lower corners furthermost from the electrode tip.

2. A feeding device, operable without opening the furnace, to insure a uniform composition for each part of the charge when making the alloys.

3. A vacuum-tight crucible which permits a fairly complete outgassing operation preparatory to melting.

4. Provision for the maintenance of a static rather than a changing argon atmosphere in the furnace, thereby reducing the quantity of impurities that were introduced with the argon.

5. The use of a high-purity argon of about 99.92% minimum argon which, with the employment of a static atmosphere, eliminated the nuisance and hazard of the purification train formerly used to purify the argon.

6. The use of a one-piece spun copper crucible of a design that would facilitate replacement of the crucible when it was damaged by arcing.

7. The control of the temperature of the cooling water and the incorporation of a proper design of the water jacket around the crucible to permit close control of cooling rate during melting.

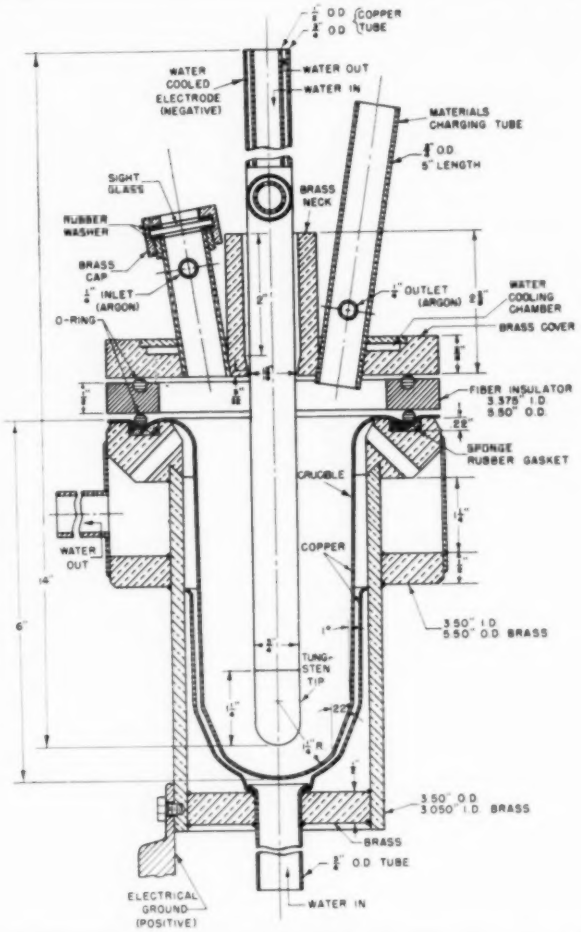


Fig. 1 — Arc-Melting Furnace of 1-Lb. Capacity

8. Two O-ring seals, one on each side of the fiber ring which provides leak tightness and electrical insulation between brass cover and crucible.

9. A water-cooled brass cover containing the sight glass, the charging tube, and the neck through which the water-cooled electrode passes.

10. A rubber sleeve between the electrode and the brass neck in the cover which provides leak tightness and at the same time permits the straight electrode to be rotated so that the tip generates a circle of radius approximately ½ in. smaller than the inside radius of the crucible.

A typical heat is made in this furnace as follows: Approximately 0.20 lb. of titanium, under ½ in. in size, with the alloy addition (if any is to be used) is placed in the bottom of the crucible. The cover is then clamped on the crucible so that the O-rings make a tight seal, and the remainder of the charge is placed in the glass bottle connected to the charging tube of the furnace with a rubber tube. The crucible and the charge are evacuated by means of a mechanical pump to a pressure below 50 mm. of mercury, or less if desired, and this vacuum is maintained for 5 min., during which time hot water is circulated through the water jacket to assist in the outgassing of the crucible. At the end of the evacuation period, tank argon of 99.92% purity is introduced into the crucible and the temperature of the water in the water jacket is reduced to about 78° F.

The generator is set for 80 volts open circuit and 250 amp., the arc is struck and the electrode withdrawn to produce an arc voltage of 25 to 30 volts, which is maintained while the electrode tip is moved slowly around a circle 1 in. smaller than the diameter of the ingot. This part of the operation requires about 1 min., after which the current is raised gradually to 500 to 800 amp., depending on the alloy addition. The electric vibrator which is attached to the bottom of the outer brass jacket is operated for about a 2-min. period, and the rate of rotation of the electrode is increased so that the whole charge will be maintained in a molten condition. At the end of this 2-min. period at 500 to 800 amp., the voltage is reduced and the vibration discontinued. The vibrator is not used again during the balance of the heat. Approximately 0.15 lb. of the charge is added from the glass container through the charging tube. The arc is maintained at a low current during charging, but is immediately reset at 500 to 800 amp. and the electrode is rotated rapidly for 1½ min. The voltage is again reduced, and the remaining 0.15-lb. charge is added to produce a ½-lb. ingot. The arc is again increased and the above operation repeated, the 500 to 800-amp. current being maintained for 2½ min. The arc current is then reduced to a minimum in order to eliminate shrinkage in the ingot while the liquid metal is solidifying. The furnace is allowed to cool for 10 to 15 min. before the cover is removed and the ingot withdrawn from the crucible.

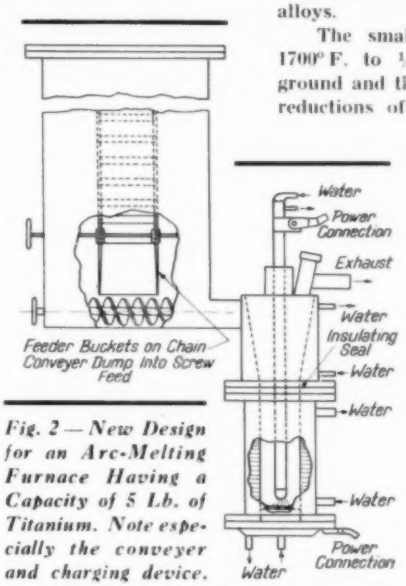


Fig. 2 — New Design for an Arc-Melting Furnace Having a Capacity of 5 Lb. of Titanium. Note especially the conveyer and charging device.

Four of these furnaces have been built and are operated together, using a single power source consisting of two 400-amp. generators connected in parallel. Although as many as sixteen ingots have been made in 8 hr. in this unit, a two-man crew usually produces an average of ten to twelve ½-lb. alloy ingots per day. An arc current up to 1800 amp. has been used with no undue difficulty in a similar unit for melting particularly refractory alloys.

The small ½-lb. ingots are forged at 1700° F. to ¼-in. slabs which are surface ground and then hot rolled at 1450° F., using reductions of 0.060 in. per pass to a final thickness of 0.064 in. Reheating between successive passes is necessary until the final reduction has been obtained. The resulting sheet is then subjected to a routine procedure for alloy evaluation.

Furnace of 5-Lb. Capacity — A furnace of 5-lb. capacity (Fig. 2) now under construction incorporates most of the design features of the smaller furnace and a more elaborate charging device which will permit production of larger ingots.

Conclusions — Although the arc-melting technique described here would not be expected to produce excellent uniformity of composition from one part of the ingot to another, relatively little difficulty has been encountered from this source except when the melting point of the alloy addition is substantially greater than that of titanium. When making ingots containing such refractory elements, special care is required and occasionally remelting is desirable to produce adequate uniformity.

Iodide titanium can be melted consistently in furnaces of the type described above with little or no increase in hardness, indicating that contamination during the melting operation is negligible. The nitrogen content of ingots of unalloyed Process A titanium has been repeatedly shown to lie in the range of 0.010 to 0.015%, values which are

only slightly greater than that of the unmelted Process A sponge.

The arc furnace is particularly well suited to the rapid production of small ingots of titanium or other refractory alloys without contamination from the atmosphere or from the crucible material. It is also adaptable to the production of larger ingots and, in many respects, the production of larger ingots in the water-cooled crucible is easier than the production of smaller ones because of a more favorable ratio of surface area to volume, resulting in a lower heat loss through the crucible wall. In addition, when large ingots having some depth are melted, the melting operation is carried out on top of the solid titanium rather than on top of a water-cooled copper base. The thermal conductivity of the titanium is low; consequently, the heat losses through the bottom are negligible and the melting efficiency increases. Furthermore, the larger diameter ingots provide greater space between the rotating electrode and the crucible wall, permitting the continuous addition of the charging material without danger of arc blowing to the crucible. The fact that the liquid titanium does not wet or adhere to the water-cooled copper wall would greatly facilitate the continuous withdrawal of the ingot from the bottom of the furnace. Although no effort has been made to produce a continuous ingot by this procedure, it is quite certain that it could be done with a relatively small amount of development.

Spot Welding of Titanium

Abstracted from a paper by
R. S. Dean, J. R. Long, E. T. Hayes
and D. C. Root*
Federal Bureau of Mines

THE HIGH ACTIVITY of titanium toward the common gases raises the question of conditions required for welding the metal successfully. The work reported here is a demonstration of the feasibility of welding titanium, rather than an exhaustive study of spot welding.

Titanium, like stainless steel, has high electrical resistivity. This similarity suggested titanium should behave somewhat like stainless, allowing considerable latitude in the several welding variables.

Surface Treatment — Titanium sheet can be welded readily without special cleaning procedures if films formed at room temperature are the only ones present. This is of considerable interest because aluminum requires careful cleaning to remove the oxide film before welding. Titanium behaves more like stainless steel in this respect. Heavier oxide coatings, such as those formed on titanium hot rolled above 900° F., must be removed before spot welding. This can be done mechanically or by pickling the metal in 5% HF. In the tests described here, all specimens were welded in the cold rolled condition without any special preparation of the surface.

Welding Current — The effect of varying the welding current was determined for sheet titanium (0.020, 0.040 and 0.064 in. thick) using a welding time of six cycles (0.1 sec.) and a tip pressure of 100 lb. The welding time was chosen after preliminary work had shown that good welds could be produced in this time interval. The tip pressure is rather low for the thickest sheet; it was selected to accommodate the thin sheet, which softens rapidly during heating. (The softening would contribute to excessive indentation and expulsion of fused metal at high currents.)

The data plotted in Fig. 1 are averages obtained from four to six welds in each condition. Representative welds were examined metallographically to check weld structure, bonding, heat-affected zones, and penetration. For the 0.064-in. sheet, penetration was negligible at 1800 amp., about 40% at 2100 amp., 70% at 2400 amp., and 85 to 90% above 2400 amp. In the range of current used, no metal was expelled from the fusion zone, and all welds were free from gas pockets. It is evident from Fig. 1 that the upper limit of welding current for sheet 0.064 in. thick was not reached in this series of tests.

(Continued on p. 252)

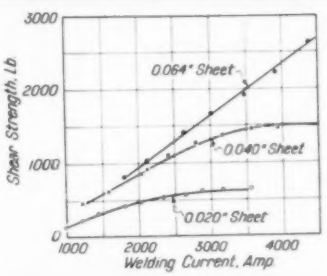
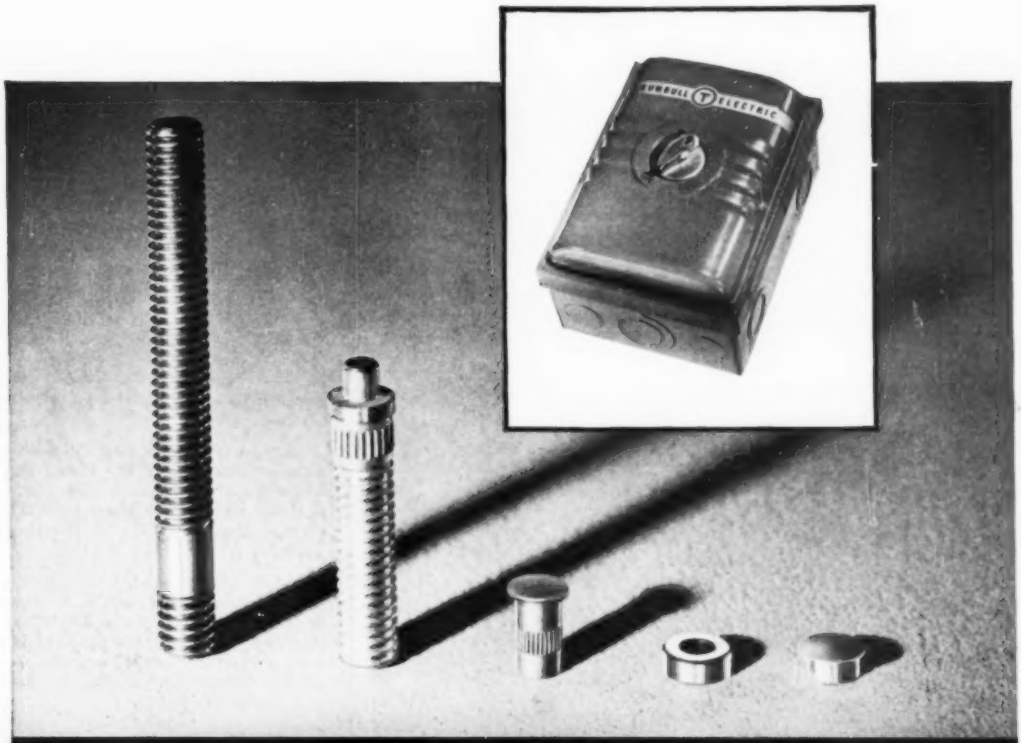


Fig. 1 — Effect of Welding Current on the Shear Strength of Titanium Spot Welds in Sheet of Three Thicknesses

*Transactions of the American Institute of Mining and Metallurgical Engineers, Vol. 171, 1947, p. 431 to 438.



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#3731, 60 amp. post stud.—5,760 pieces run in 19.6 hours with no machine down-time; 10,425 pieces of ordinary copper rod run in 66.6 hours with 11.8 hours machine down-time. In addition to the extra time required, three sets of dies were used for the regular rod. "The savings of the free-cutting material over ordinary copper were figured at $1.81 per thousand, including in these costs both material and direct labor."

#16552, space washer. "Savings per thousand over electrolytic copper were 77¢. This figure included the material difference and direct labor. In addition, there was an 18% saving in machine down-time."

#K-60-1A, 70-200 amp. stud. "The use of Free-Cutting Copper Rod on this part very definitely increased production and practically voided machine down-time."

In a letter to Revere, Trumbull added: "In general, at least for most of the parts we have used, we find that there is at least a 25% saving in machine time of free-cutting over regular copper. In addition, the workers are enthusiastic about this material, particularly when running studs, because of the fact that it is no longer necessary for them to keep a constant close watch on the machine to see that the turnings do not become tangled up with the moving parts of the machine."

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PERSONALS

Kent R. Van Horn (past-president ⊖), chief of the Cleveland branch of Aluminum Co. of America's Research Laboratories, has been named an assistant director of research of the company. **Maurice W. Daugherty** ⊖, assistant chief of the Cleveland laboratories, becomes chief. Dr. Van Horn will remain in Cleveland, continuing to direct research on casting and forging processes and alloys.

Banks E. Eudy ⊖ has been appointed manager of the new stainless steel sales division of the American Steel & Wire Co. **C. Richard Horwedel** ⊖ is assistant manager. Mr. Eudy, formerly with Allegheny Steel Co. and Carnegie-Illinois Steel Corp., has been heading a stainless unit at American Steel & Wire since 1947. Dr. Horwedel has been with the metallurgical department of the company since 1930.

D. M. Horner ⊖ has been appointed a vice-president of Harrisburg Steel Corp., Harrisburg, Pa.

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T. H. McConica ⊖ has resigned as assistant to the general manager of the Magnesium Division, Dow Chemical Co., Midland, Mich., to devote his entire time to the American Ski Co., Clare, Mich.

Midwest Research Institute, Kansas City, Mo., announces the promotion of **Clayton O. Dohrenwend** ⊖ from research consultant to assistant director. He was formerly associated with the Illinois Institute of Technology.

William T. Bean, Jr., ⊖, formerly project engineer for Continental Aviation and Engineering Corp., has established a consulting service in product design and development in Detroit.

Allegheny Ludlum Steel Corp. announces that **Robert M. Arnold** ⊖, a director of the company and president of Arnold Engineering Co., Chicago, has been elected a vice-president.

Bliss & Laughlin, Inc., announces the appointment of **Robert W. Ritchie** ⊖ to head its newly established office in Indianapolis, Ind. Mr. Ritchie has been a sales promotion engineer at the Harvey, Ill., general office for the past few years.

Columbia Tool Steel Co. announces the appointment of **Gilbert R. Jarman** ⊖ as district sales manager of the St. Louis territory. Mr. Jarman has represented the company in the Chicago district for several years.

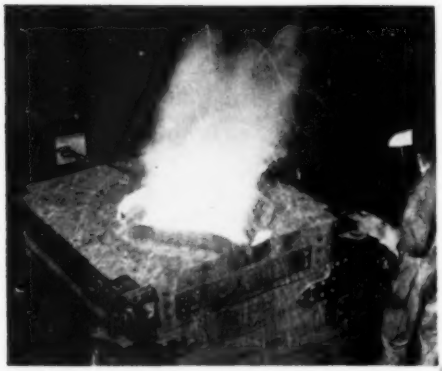
Harold M. Cobb, Jr., ⊖ has resigned from the Piasecki Helicopter Corp. to accept a position as metallurgist at Westinghouse Electric Corp., Aviation Gas Turbine Div.

Leaving the materials laboratory of Wright-Patterson Air Force Base, **Jay R. Burns** ⊖ has joined the process development department, Magnesium Div., Dow Chemical Co., Midland, Mich.

After graduating from the University of Pittsburgh's metallurgical engineering school, **Alfred E. Gould** ⊖ accepted employment with McConway & Torley Corp., Pittsburgh, as a sand control technician.

Jack J. Bodzin ⊖ has been appointed a junior metallurgist by the Hudson Motor Car Co., Detroit, upon graduation from the Michigan College of Mining and Technology.

Following graduation from the University of Cincinnati in July 1948, **Robert B. Day** ⊖ is now employed by the Linde Air Products Co. in its cylinder maintenance and testing department.



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PERSONALS

After graduating from Case Institute of Technology in June 1948, **Henry C. Miller, Jr.,** entered the employ of the Forest City Foundries Co., Cleveland, where he is now a member of the sales department.

William A. Tripp has been promoted from an assistant in the metallurgical laboratory of Rotary Electric Steel Co., Detroit, to metallographer with the same company.

Everett J. Roach is now employed as a materials engineer with Western Electric Co., Kearny, N. J.

William H. Wilson, formerly with Oak Ridge National Laboratory, is now materials engineer in the nuclear power group within the Bureau of Ships, U. S. Navy, Washington, D. C.

Clarence T. Fletcher, formerly with Mack Mfg. Corp.'s research division, is now assistant metallurgist for Braeburn Alloy Steel Div., Continental Copper and Steel Industries, Inc., Braeburn, Pa.

Formerly with Sylvania Electric Products, **R. E. Mahr** has become associated with the central engineering powder metals laboratory of Chrysler Corp., Detroit.

Allan L. Brooks is at present employed as a metallurgist in the standards engineering materials laboratory of Sperry Gyroscope Co., Lake Success, L.I., N.Y.

Pasquale Silimperi is now research engineer for Bethlehem Steel Corp., Bethlehem, Pa.

After receiving his degree of Ph. D. from Ohio State University, **R. Tracy Eddinger** has accepted a position as research engineer with the Pittsburgh Consolidated Coal Co.'s research and development division in Library, Pa.

Edwin Shifrin, formerly with General Motors Research Laboratories, is now assistant welding engineer of the Detroit Edison Co.

Richard J. McCafferty, formerly manager of experiment and research of Lochmoor Mfg. Co., Detroit, is now design engineer with Douglas Aircraft Co., Long Beach, Calif.

William J. Mulvehill has recently been promoted from chief research engineer to chief metallurgist at the Motch & Merryweather Machinery Co., Cleveland. Until a year ago he was superintendent of heat treatment at Firestone Steel Products, Akron, Ohio.

Charles E. Vogelsang, formerly grinding engineer of J. K. Smit & Sons, New York City, is now standards engineer and consultant on grinding methods for Fairbanks, Morse Co., Beloit, Wis.

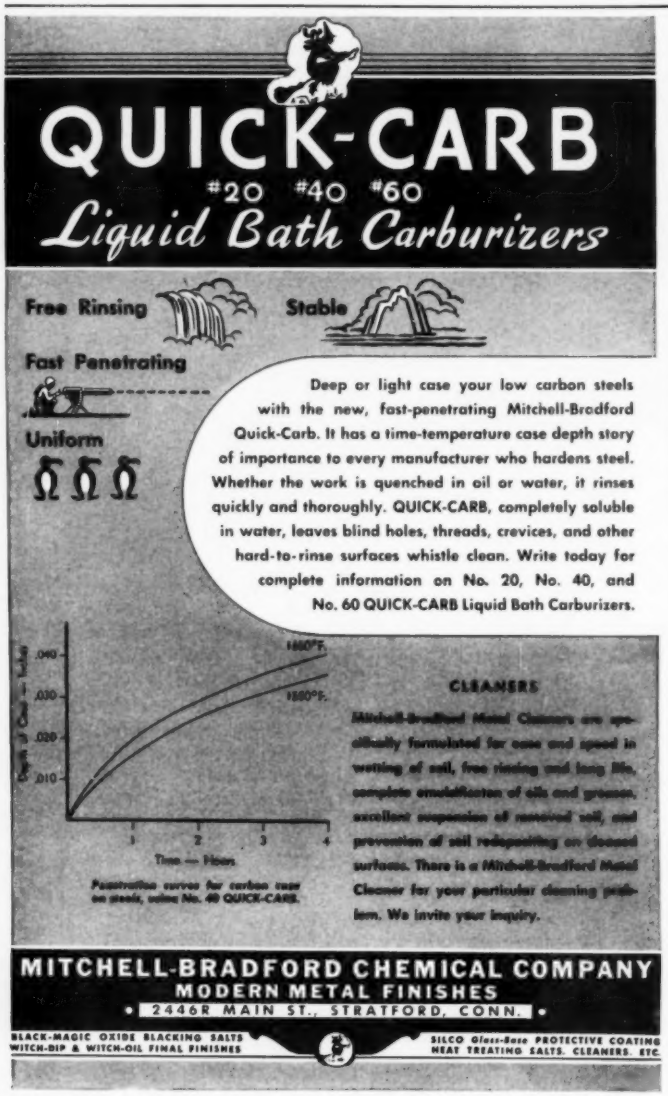
Following completion of his college training at the University of Pittsburgh in June 1948, **William L. Gleason** has been with Bethlehem Steel Co. taking its loop course and is now at the Johnstown, Pa., plant.

Carl Ludwig is now with the Bonnot Co., Canton, Ohio.

Martin S. Miller has joined Lucius Pitkin Laboratories, New York City, as metallurgical assistant.

Leon A. Cybul, formerly in the metallurgical research departments of Ford Motor Co. and Timken-Detroit Axle, is now a sales representative with the Trenton Chemical Co., Trenton, Mich.

B. D. Malani is now an engineering trainee with the Baldwin Locomotive Works, Philadelphia.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Deep or light case your low carbon steels with the new, fast-penetrating Mitchell-Bradford Quick-Carb. It has a time-temperature case depth story of importance to every manufacturer who hardens steel. Whether the work is quenched in oil or water, it rinses quickly and thoroughly. QUICK-CARB, completely soluble in water, leaves blind holes, threads, crevices, and other hard-to-rinse surfaces whistle clean. Write today for complete information on No. 20, No. 40, and No. 60 QUICK-CARB Liquid Bath Carburizers.
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Penetration curves for carbon case on steels, using No. 40 QUICK-CARB.
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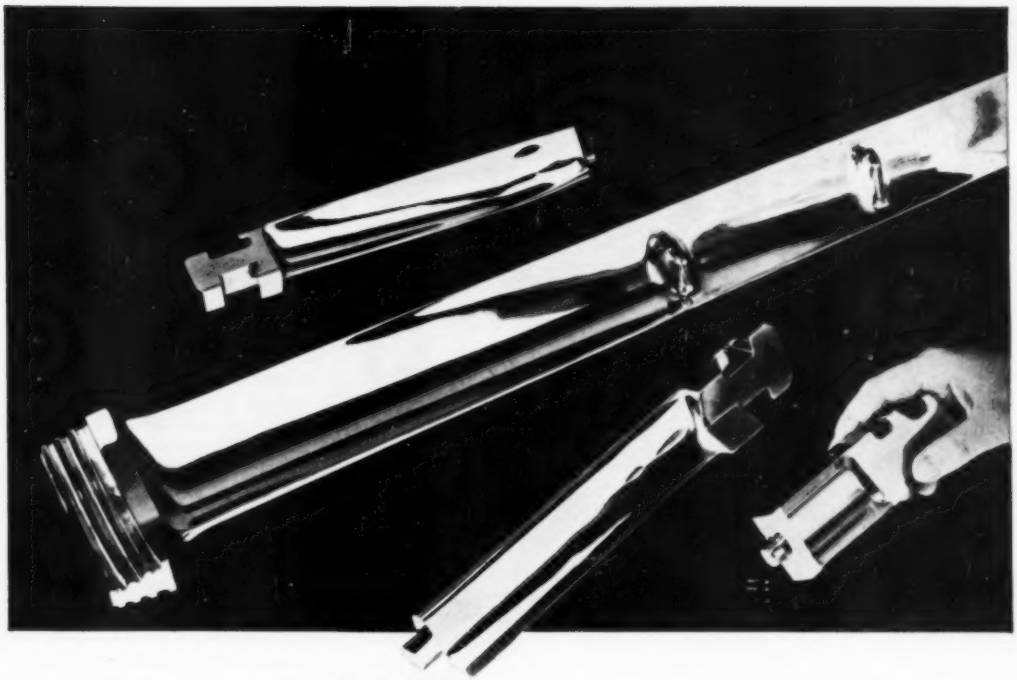

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High strength, toughness and corrosion-resistance make stainless steel the ideal material for steam turbine blades—but there's another quality needed, too—WORKABILITY. And you'll find it well developed in Republic ENDURO.

ENDURO responds uniformly in forging—as demonstrated by the largest blade above which was forged from a 7½" x 3" bar. All four blades indicate that a substantial amount of machining was necessary—and here again ENDURO shines, particularly in the free-machining grades.

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SAVE TIME!
Every week G. O. Carlson, Inc., publishes a list of plates in stock, by analyses. Have this up-to-the-minute data always at hand when you need it. A brief note to us will put you on the list immediately.

PERSONALS

Nicholas A. Wagner has been transferred by Reynolds Metals Co. from Louisville, Ky., to Reynolds Alloys Co., Sheffield, Ala., where he is development metallurgist.

Mike Lauriente is now working for the Pittsburgh Lectromelt Furnace Corp. as a field engineer.

George H. Hatfield has recently been appointed district manager for Texas, New Mexico and Louisiana, for Wheelco Instruments Co. His headquarters are in Houston, Texas.

Frank B. Rogers is now a metallurgical engineer in the department of metallurgy and inspection, Granite City Steel Co., Granite City, Ill.

Frank G. Foote, formerly associate professor of metallurgy, School of Mines, Columbia University, is now director of the metallurgy division, Argonne National Laboratory, Chicago.

Laurence E. Brown is now employed as senior test engineer in the engineering research division of the Wright Aeronautical Corp., Woodridge, N. J.

Herbert S. Kalish, formerly a research metallurgist at the Electric Storage Battery Co., Philadelphia, is now a metallurgist at Sylvania Electric Products, Inc., Bayside, L.I., N.Y.

James D. Flynn, Jr., is now a chemical engineer at Carbide & Carbon Chemical Corp., Oak Ridge, Tenn.

Lawrence G. Glasgow is now employed as a metallurgist in the materials laboratories of Chance-Vought Aircraft, Stratford, Conn.

Edward C. Hanna, formerly manager of Rhode Island Tool Co., is now assistant works manager of Landis Machine Co., Waynesboro, Pa.

J. W. Spretnak has accepted an appointment as associate professor of metallurgy at the Ohio State University, Columbus. He was formerly a member of the staff of the metals research laboratory of the Carnegie Institute of Technology.

Lewis N. Rohrbach has been transferred from the War Assets Administration in Detroit to inspector for the Army Air Force at the Cleveland Pneumatic Tool Co.

Theodore E. Burke, formerly a field metallurgist for Republic Steel Corp., is currently with the Vanadium Corp. of America as a sales engineer in the Chicago area.

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SPECIMEN MOUNT PRESS

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This new, improved model is designed specifically for the rapid precision molding of specimen mounts, either in bakelite or transparent plastic. The simple, rugged construction, without concealed working parts, offers maximum accessibility and convenience for the operator. This accessibility combined with the smooth performance of this press, permits speed and accuracy in molding specimen mounts.

Molding tools are lapped finished for close tolerance with a perfect fit. The fast working solid heater can be raised and the cooling blocks swung into position without releasing pressure on the mold. This rapid cooling permits removal of transoptic mounts in a few minutes. Heater and cooling blocks need not be removed from the press thus eliminating the possibility of accidental burns in handling these parts. This model press will develop pressure up to 10,000 lbs.

THE BUEHLER line of specimen preparation equipment includes . . . .
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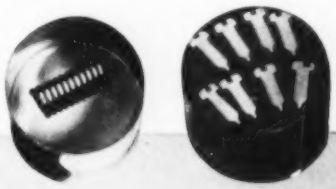

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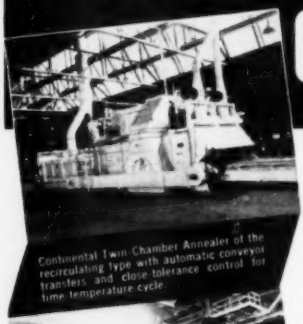
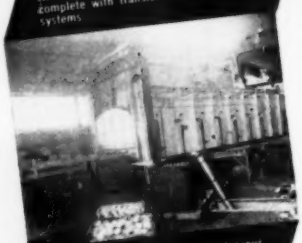


Continental Twin-Chamber Annealer of the recirculating type with automatic conveyor transfers and close-tolerance control for time-temperature cycle.

Two Continental Continuous Controlled Atmosphere Annealers, roller rail type, complete with transfer cars and conveyor systems.



Continental Stamping Annealer, continuous roller rail type, complete with baskets, handling conveyors, and automatic controls for work handling and temperature cycles.

Six Continental "Top Hat" Cover Type Furnaces, for bright annealing high carbon steel, complete with gas generator and automatic controlled time-temperature cycling.

problems to results . . .

As varied as the problems were in these heating process requirements, CONTINENTAL produced the solutions. We have the answer to your problems, too.

CONTINENTAL planned performance starts with the analysis of your problem and production requirements. It carries through with the selection and development of the best methods, estimates costs and savings, designs and builds the equipment, and provides the work-handling accessories and control devices. Furthermore, CONTINENTAL handles the complete installation, turning over to you a unitized, producing job with guaranteed results.

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PERSONALS

Fred P. Peters, who for several years has been associate publishing director of the book division and editor-in-chief of *Materials & Methods*, Reinhold Publishing Corp., has been elected vice-president of the corporation and publishing director of the book division. He will continue as editorial director of *Materials & Methods*. **Theodore C. Du Mond**, who has been managing editor of *Materials & Methods* since 1945, has been named editor of the magazine.

W. P. Ruemmler is now acting general superintendent and head of development at the East Chicago plant of the Eagle-Picher Co.

John H. O'Connell, formerly heat treating equipment supervisor, is now president and superintendent of the Quality Heat Treating Co., Inc., Sterling, Ill.

V. G. G. Nayar, who has been associated with the Aluminium Co. of Canada and Aluminium Laboratories, Ltd., during the past year, has returned to India where he will be works manager of M/s Aluminium Industries, Ltd., Kundara, Travancore.

James L. Foster, formerly research engineer for Battelle Memorial Institute, has been appointed metallurgist at the wheel and brake division, Goodyear Aircraft Corp., Akron, Ohio.

After a year of touring the plants of Phelps Dodge in Yonkers, N. Y., Bayway, N. J., and Fort Wayne, Ind., **J. McNeal Wheatley** has been named salesman for the company, covering Illinois, Iowa and southern Wisconsin.

James T. Gow, formerly of Battelle Memorial Institute, is now chief metallurgist of Electric Furnace Castings Co. at Portland, Ore.

The Etter Engineering Co. of Wallingford, Conn., announces the appointment of **Joseph M. Halloran** as sales engineer for the southern Connecticut area. He will represent Eclipse Fuel Engineering Co., Despatch Oven Co. and Partlow Corp. Mr. Halloran was previously with the A. F. Holden Co.

Charles H. T. Wilkins, formerly metallurgist with the Copperweld Steel Co., will work on the technology of fine wire products at Mellon Institute in Pittsburgh under a fellowship established by the National-Standard Co. of Niles, Mich.

How THE PRESSED STEEL CO. CONTAINERS

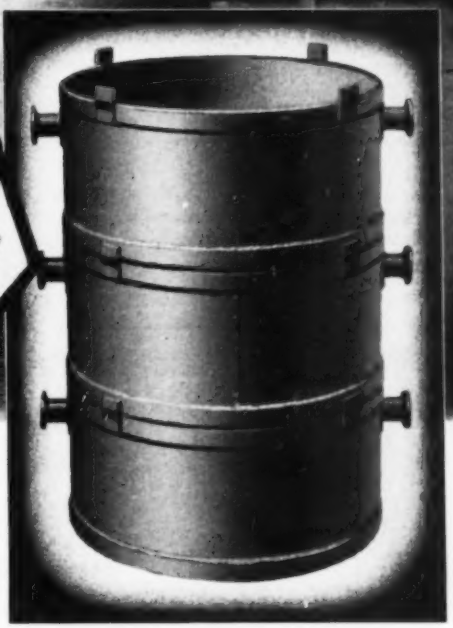
CUT HEAT-TREATING COSTS

The sheet alloy baskets, pictured at right, were fabricated by The Pressed Steel Co. to replace cast alloy baskets in a battery of gas carburizing furnaces. In contrast to a maximum life of 3,000 hours for the old baskets, the sheet alloy units were still in good condition after 20,000 hours. This represents a substantial saving in replacement costs. But now add these further savings, resulting from the fact that the sheet alloy baskets weigh 2/3 less:

1) FUEL SAVING--Need less time to attain pot heat.
2) LABOR SAVING--Handle easier and faster.
3) SPACE SAVING--Increase furnace capacity.

Equipment for Every Heat-Treating Purpose

"Pressed Steel" light-weight sheet alloy heat-treating units are furnished in any size, design or metal specification: boxes, covers, baskets, racks, tubes, retorts, etc. As pioneers of welded alloy heat-treating equipment, we offer you a wealth of experienced engineering assistance and production know-how. Send blue prints or write as to your needs.



Light-weight sheet-alloy basket to replace cast units in a battery of carburizing furnaces. "Pressed Steel" fabricates containers and covers for every heat-treating purpose.

THE PRESSED STEEL COMPANY
of WILKES-BARRE, PENNSYLVANIA

Industrial Equipment of Heat and Corrosion Resistant WEIGHT-SAVING *Sheet Alloys*

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PERSONALS

Leon Eriv has left the Hamilton Watch Co. at Lancaster, Pa., to become research assistant at the Fritz Engineering Laboratory of Lehigh University.

After graduation from Carnegie Institute of Technology in June 1948, **Robert D. Fitzgerald** has rejoined the metallography division of the Aluminum Research Laboratories of the Aluminum Co. of America in New Kensington, Pa., as assistant metallographer.

Thomas E. Gregory, formerly foundry metallurgist at Cramp Brass & Iron Foundry of Baldwin Locomotive Works, is now a metallurgist for Firestone Tire & Rubber Co., Akron, Ohio.

In addition to his previous duties as chief metallurgist of the Navy Bureau of Aeronautics, **N. E. Promisel** is now also head of the materials branch, which is responsible for the research, development and control of all materials and processes used in the construction of naval aircraft.

J. A. Kroll has recently joined the Atlantic Saw Mfg. Co., Inc., New Haven, Conn., as general superintendent. For the past two years he has been chief production engineer for the Spotlite Corp. and technical consultant for the American International Transactions Corp.

Gardiner D. Spring, formerly industrial lubrication salesman with Socony-Vacuum Oil Co., Inc., is now manufacturer's representative of refrigeration supplies for New England. His headquarters are in Worcester, Mass.

V. H. McBride has recently been appointed superintendent of inspection at Reaction Motors, Inc., Dover, N. J.

Donald K. Stevens, who was formerly metallurgist at Oak Ridge National Laboratory, is now physicist in the division of physical metallurgy at the Naval Research Laboratory, Washington, D. C.

Earl O. Smith, formerly metallurgist at the Vandergrift plant of the Irvin, Pa., works of Carnegie-Illinois Steel Corp., has been transferred to the McDonald, Ohio, plant.

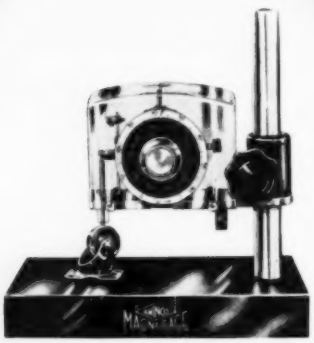
James C. Wilson, formerly an assistant in the department of metallurgy at the University of Cincinnati and with the Lunkenheimer Co. and Hamilton Foundry and Machine Co., has been appointed as an instructor in metallurgy at Lafayette College, Easton, Pa.

Stuart K. Oliver, formerly in charge of the Lindberg Engineering Co.'s Cleveland office, will be manager of the new West Coast office of the company at Los Angeles. The new headquarters will serve the states of California, Oregon and Washington.

Following graduation from Ohio State University, **Robert G. Kline** has accepted a position as a research engineer in the welding division of Battelle Memorial Institute, Columbus, Ohio.

J. Wesley Cable, formerly director of research and sales of the Induction Heating Corp., has opened offices as a consultant to the high frequency heating field in New York City. He will specialize in both induction and dielectric heating, and will offer complete engineering and design service to industry.

MEASURE THICKNESS OF COATINGS ON METALS THE EASY, ACCURATE WAY



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FOR MEASURING THICKNESS OF NON-MAGNETIC COATINGS ON IRON OR STEEL AND NICKEL COATINGS ON IRON, STEEL, OR ANY NON-MAGNETIC MATERIAL

The Magne-Gage is a versatile, easy-to-use instrument for accurately measuring coatings on convex, concave, or plane surfaces, without destroying either the coating being measured or the base material. Modified Magne-Gages can be supplied to measure coatings on inside surfaces of tubes, pipes, etc. Less than 45 seconds are required to take a reading, and an accuracy of better than 10% full-scale is assured. Operation is based on the magnetic attraction of a permanent magnet to the material being measured and/or its backing, thus no electrical circuits are involved and no auxiliary equipment is required.

A special Magne-Gage is available for measuring composite copper-nickel coatings on steel.

SEND FOR FREE BULLETIN NO. MP-2150, DESCRIBING THE MAGNE-GAGE AND OTHER COATING THICKNESS GAGES

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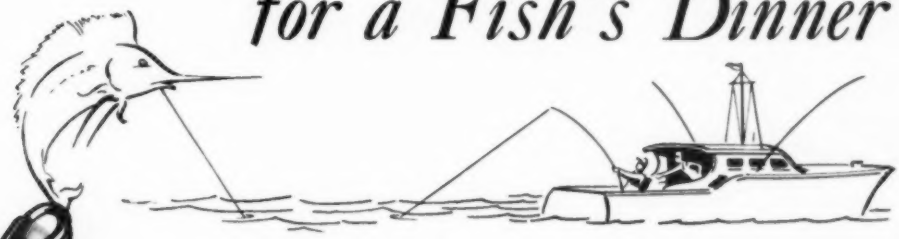
STAINLESS "SPOON"
for a Fish's Dinner



Courtesy Wm. J. Hunt Mfg. Co.

Mackerel, stripers, sailfish, even trout go for this stainless Drone—a flashing, darting imitation of live bait, expertly designed to lure hungry heavyweights to a final meal.

Originally made of lacquered nickel-silver, these spoons are now made from stainless steel for lasting brilliance. First trials with stainless, however, were disappointing. The usual commercial grades gave trouble—buffing, even electro-polishing could not bring out the brilliance necessary for an effective lure. Again, these grades proved too soft to properly lock the hook—and hold it in the first lunge of a strike.

The Frasse recommendation was stainless steel of the same analysis—but rolled with a special temper. Result—a more rigid spoon with a properly seated hook, and a more appetizing gleam while trolling. Added advantages included production increases in stamping and forming, and reduced time cycle in polishing bath.

Frasse stocks stainless steel in every commercial form—bars and sheets, strip and tube—even valves, pipe fittings and electrodes. But Frasse stainless *engineering* service is equally handy—and just as useful. For stainless steels, and qualified engineering suggestion in their application—call Frasse. *Peter A. Frasse and Co. Inc., 17 Grand Street, New York 13, N. Y. (Walker 5-2200) • 3911 Wissahickon Avenue, Philadelphia 29, Pa. (Baldwin 9-9900) • 50 Exchange Street, Buffalo 3, N. Y. (Washington 2000) Jersey City • Syracuse • Hartford • Rochester • Baltimore.*

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THE PRODUCTION OF STEEL IN GERMANY*

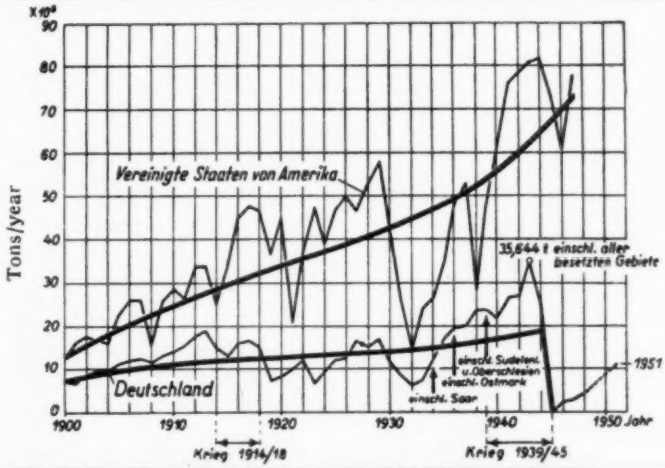
IN THE AUTUMN of 1947, the steel production of the bizonal area of Germany had reached a level of 2.9 million metric tons, but the upward trend of production was impeded by insufficient allocations of solid fuel (and the consequent inadequate production of gas, power, lime, refractories and other auxiliary materials), the import ban on high-grade foreign ores, the increased export of scrap from Germany, and many other factors. In February 1948, the steel industry of Germany was ordered to bring production up to a level of 6 million tons per year, and at the time this article was written (September 1948) the industry was contemplating a revised plan with a permitted output of 10.7 million tons per year. The author discusses the difficulties that stand between this objective and its fulfillment.

The accompanying graph shows the German and American steel production since 1900. The collapse of German production in 1945 could scarcely have been more complete. The dotted line from 1948 to 1951 indicates the "goal of [the author's] boundless dreams" for the German steel industry.

The matter of blast furnace burden has been rather a sore point during the occupation. Originally the British maintained the position that there was to be no smelting of

(Continued on p. 214)

*Abstracted from "10.7 Million Tons of Steel — But How?", by Paul Voltz, *Stahl und Eisen*, Vol. 68, 1948, No. 23/24.



Steel Production in Germany and the United States Since 1900, in Metric Tons

Control Equipment needn't be costly—

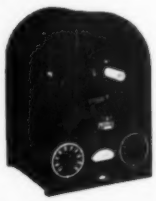
look at these prices

With the Dietert Carbon Determinator, you can get carbon content of metals to an accuracy of one-half point in two minutes. Other materials having up to 60% carbon are tested with comparable accuracy.

The PRICE is $235.00

The sulfur content of metals and other materials can be just as accurately obtained by the Dietert Sulfur Determinator in three minutes.

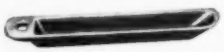
The PRICE is $153.00



The Dietert Varitemp Furnace used in the combustion of samples for carbon and sulfur determination develops temperatures under close control up to 2750° F.

The PRICE is $228.00

Zircotube combustion tubes have especially long service life and even at temperatures of 2800° F. they do not crack, sag or become porous. They resist thermal shock and metal splatter.



Dietert Combustion Boats likewise are highly refractory, resist metal shock and metal penetration.

The PRICE is $49.00 a thousand

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Bulletin 4361 describes the complete line of Alnor pyrometers with details on scale ranges, prices, special fittings etc. Your copy will be mailed to you at once on receipt of the coupon below.

Watching the temperature is an important part of quality control all over the industrial map—for die-casting, heat-treating, bake-oven work, etc.—and no batch is better than the pyrometer which measures its temperature. That's why so often you'll see battery after battery of heat-treating furnaces, bake-ovens, etc., equipped with Alnor Type RM pyrometers. These inexpensive single circuit units are precise instruments, water-proof, dust-tight, and fume-proof. They are easily mounted, quickly hooked up. Manual cold-end compensator is standard equipment although an automatic compensator can be furnished if desired. Type RM pyrometers are available in scale ranges from 0-400 degrees Fahrenheit to 0-3000 degrees Fahrenheit, and equivalent Centigrade scales can be furnished.

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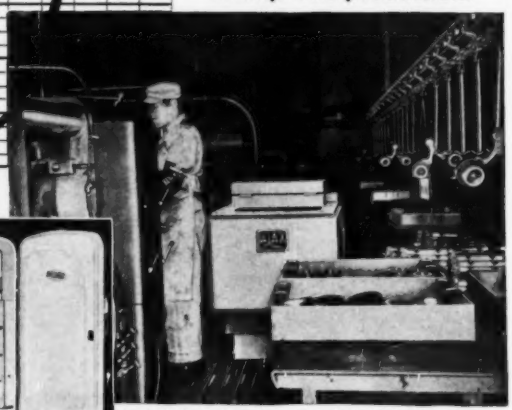
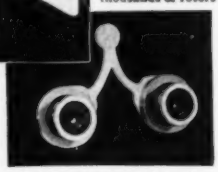
Electric Motors produced monthly in the U.S.A. --more and more manufacturers are installing

AJAX ELECTRIC FURNACES to improve production.



Part of the modern die casting plant of the Westinghouse Electric Corporation in Springfield, Massachusetts, where thousands of rotors are cast every day for refrigerator units.

The new Westinghouse Refrigerator Model MF-7.



Cast two at a time, these aluminum motor rotors are better because of accurate temperature control and freedom from contamination made possible by Ajax Induction Furnaces.

Included in the millions of motors manufactured nationally, per month, are the hundreds of thousands of fractional horse-power motors that fill the ranks of faithful, alert and silent servants for the American home. Such large output requires ingenious production methods. A great improvement has been achieved by casting the rotors from high purity aluminum. Prominent manufacturers have recognized the advantage of using Ajax-Tama-Wyatt induction furnaces for melting the aluminum prior to casting, because of the accurate temperature control and freedom from contamination with iron or silicon.

Write today for information about this modern method of increasing precision production.

AJAX ENGINEERING CORPORATION
TRENTON 7, NEW JERSEY

AJAX TAMA-WYATT **INDUCTION MELTING FURNACE**

Associate Companies: **AJAX METAL COMPANY**, Non-Ferrous Ingot Metals and Alloys for Foundry Use
AJAX ELECTROTHERMIC CORP., Ajax Northrup High Frequency Induction Furnaces
AJAX ELECTRIC CO., INC., The Ajax-Hultgren Electric Salt Bath Furnace
AJAX ELECTRIC FURNACE CORP., Ajax-Wyatt Induction Furnaces for Melting

THE PRODUCTION OF STEEL IN GERMANY

(Continued from p. 212)

foreign ores in Germany. But when it became apparent that such a restriction would necessitate a greater blast furnace capacity and, in particular, a rescinding of the order to dismantle the Reichswerke, it was decided by the occupying powers that 4 million tons of Swedish ore per year would be made available to the German steel industry. Because such imports can be paid for only by an equivalent export, the author would rather see the German steel industry allowed to work out its own blast furnace problem, using as much domestic ore as possible.

The steel industry is at present unable to supply the mechanical industries with enough metal so that they can produce the parts and equipment needed to keep the steel mills and other industrial plants in running order. Normally the metallurgical industry had a close relation with the mechanical and electrical industries that supplied these spare parts and equipment (rolling mills, locomotives, engines, motors, compressors, cranes, hoists, boilers, pumps, control instruments, bearings, etc., etc.). But many of these suppliers have vanished from the face of the earth. Furthermore, according to the author, the list of the machine plants to be dismantled is a fairly comprehensive index of the manufacturers that would normally supply the spare parts to keep the steel mills in running order.

These conditions find expression in the statistics representing the repair hours per ton of ingot steel. The number of repair hours is now three or four times the normal number. More intensified use of steel mill machinery results in greater wear and tear, more breakage and increased repair work. A spare part cannot be installed because there is none. The necessary makeshift repair soon leads to a new manufacturing trouble. Laborers that would normally be employed directly in the production of steel must now join the riggers, electricians, furnace masons and other repair and maintenance squads. A committee for the rationalized maintenance of plants has been organized to find a way out of the spare parts dilemma.

To help you make

BETTER FORGINGS

Whether you specialize in drop, upset, press or smith forgings, Bethlehem Alloy Steels will go a long way toward helping you turn out better products. They are strictly top-grade steels made expressly for the purpose.

First—they are manufactured to meet requirements for close chemical analysis, proper grain structure, and uniform mechanical properties after heat-treatment.

Second—they have prepared surfaces and are internally sound. Careful mill practice insures the minimum occurrence of seams, pipe, cooling cracks and non-metallic inclusions.

Besides furnishing the alloy steels you need, we also offer complete metallurgical service. Our metallurgists will gladly give advice on problems concerning analysis, forging methods and heat-treatment. They will spare no effort to help you improve your products and reduce your costs.

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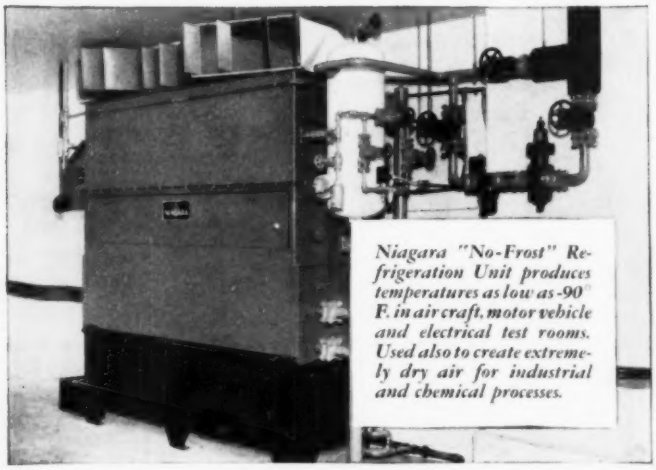
INCREASED PRODUCTION AND A MORE UNIFORM PRODUCT WITH A *Controlled Atmosphere*



Niagara "No-Frost" Refrigeration Unit produces temperatures as low as -90° F. in air craft, motor vehicle and electrical test rooms. Used also to create extremely dry air for industrial and chemical processes.

● A controlled atmosphere may be a particular gas, inert or reactive, or it may be air under controlled conditions of purity, temperature or moisture content. Its purpose is to further production or prevent loss of material or product, or to make a uniform and better product.

This Company has worked for many years among such problems and has developed special apparatus that has helped many industrial leaders to improve their manufacturing.

Always, there is a problem of moisture and temperature, whether it may be a special gas atmosphere for heat treating, or air under most precise specifications for a process with hygroscopic materials, or a "cold test" room at -90° F.

Niagara Units for industrial air and gas conditioning make it easier for you to find equipment that will produce the conditions you need with both installation and operating economy.

Write for a Niagara Blower Bulletin on a subject which interests you, or for the address of the nearest Niagara Field Engineer.

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STRATEGIC MINERALS*

THE MINERAL INDUSTRY has two major branches — the petroleum industry and the mining industry. The former had its difficulties in World War II but was able to meet them with a large degree of success. However, the mining industry of the United States differed from almost all other domestic industries in that it reached peak production very early and then suffered a significant decline. In this respect it differed also from the pattern of earlier wars, in each of which the mining industry expanded greatly. However, after Pearl Harbor there was a major reverse of this previous trend for almost all the domestic mining industry except coal.

Our prewar stockpiling program was extremely modest in most of its estimates, and there was very little material on hand in stockpiles at the time of Pearl Harbor. In addition, extensive exploration programs during the war revealed few new domestic mineral deposits of major importance.

The three major factors contributing to the decline of the domestic mining industry during World War II were a man-power shortage, an equipment shortage, and a poorly defined chain of command from the Federal Government to the mining enterprise.

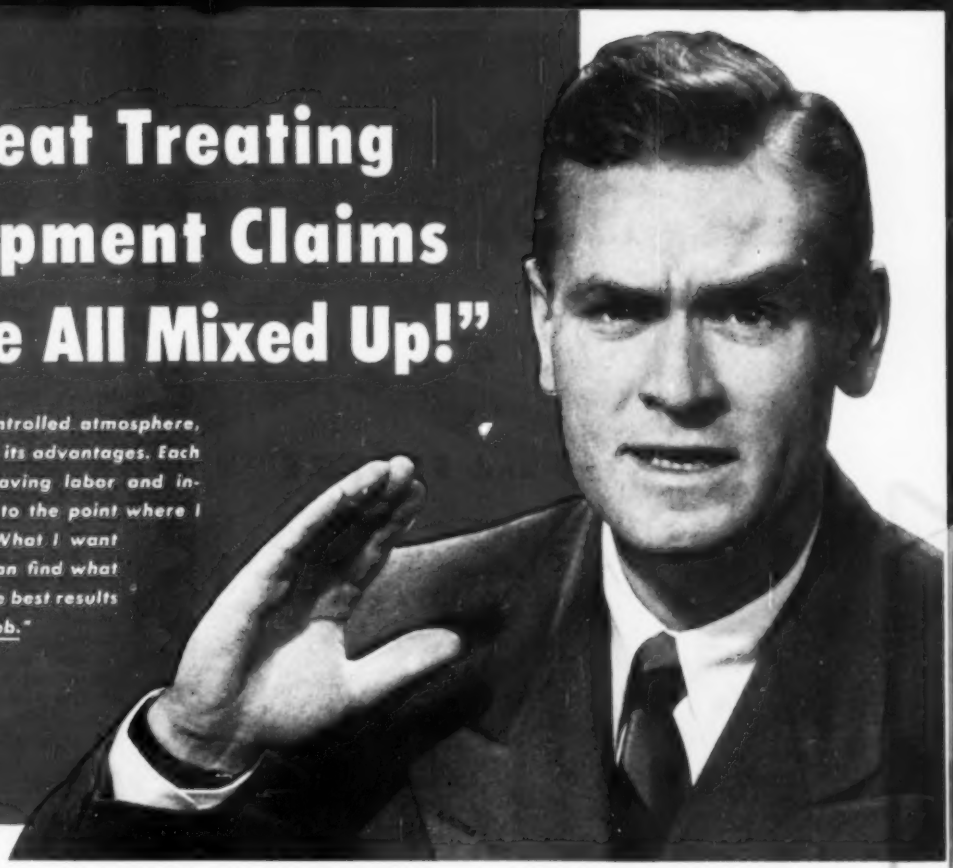
The man-power shortage was occasioned partly by the drift of skilled workers from the mines under the prewar stimulation of higher wages and longer hours in airplane factories and shipyards, and partly by the demands of the selective service which drafted 126,000 miners from a total of 606,000 miner registrants.

The equipment shortage was caused by the demands of the armed services for heavy equipment, such as heavy-duty trucks, Class I tractors, and power shovels. While the supply situation in the field of underground machinery was a little easier, here there were also major shortages caused by the fact that our manufacturers of underground mining machinery were supplying not only the United States

(Continued on p. 218)

*Abstract of "Mineral Base of War", by Maj. John D. Morgan, Jr., Corps of Engineers, U. S. Army, *Ordnance*, Jan.-Feb. 1949, p. 259.

"Heat Treating Equipment Claims Get Me All Mixed Up!"



"Gas, electronic, controlled atmosphere, salt bath! Each has its advantages. Each is advertised as saving labor and increasing efficiency to the point where I get all confused. What I want to know is how I can find what equipment will give best results on my particular job."

Despite the tremendous progress in all types of equipment, it is obvious that the *perfect* heat treating method has not yet been found—and probably never will. Thus, furnace selection becomes a matter, not so much of reading the ads, as of marshalling actual performance features of competing types, then basing judgment on indisputable facts as *they pertain to your particular job.*

We make our share of claims for Ajax Electric Salt Bath Furnaces, too. Beyond these, however, and by way of *specific proof,* we offer the services of the Ajax Metallurgical Laboratory.

The Laboratory service plan is simply this: Let us heat treat a batch of your materials here under shop conditions and in your presence. Let us make it easy for you to see and evaluate the Ajax salt bath method in actual working test before making your heat treating equipment investment!

Hundreds of leading concerns have already taken advantage of this opportunity and a large percentage of them are now among the users of Ajax furnaces.

There is no cost or obligation on your part. It is simply that we prefer to sell equipment on a definite performance basis—and, also that this policy accounts in large part for the tremendous increase in Ajax Electric Salt Bath Furnaces throughout industry as well as for the high degree of heat treating satisfaction they deliver.

***TIPS AND TRENDS** . . . This Ajax publication issued periodically, helps keep you abreast of salt bath heat treating methods, developments and "know how". Get your name on the list to receive it regularly.*

OVER 3,000 INSTALLATIONS *(more than all other electric salt baths combined)* — for

CARBURIZING
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NEUTRAL HARDENING
ANNEALING or HARDENING STAINLESS STEEL
BRAZING
HARDENING HIGH SPEED STEEL
AUSTEMPERING
MARTEMPERING
PROCESS ANNEALING
CYCLIC ANNEALING
DRAWING (TEMPERING)
SOLUTION HEAT TREATMENT
DESCALING
DESANDING
CLEANING

AJAX HULTGREN **ELECTRIC SALT BATH FURNACES**

AJAX ELECTRIC COMPANY, INC.

"FALLS BRAND" ALLOYS
AMERICA'S LARGEST PRODUCERS OF ALLOYS

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BRASS and BRONZE

"FALLS" Flux "B" cuts melting costs by reducing rejections and scrap caused by dirty metal.

1. It increases metal yield about 3% by putting all the metal usually lost in the dross back into the molten metal.
2. It cleans, fluxes and removes gases, oxides and non-metallic impurities from all grades of brass and bronze.

A dry white powder, "FALLS" Flux "B" does not smoke, fume or smell, will not absorb moisture, and can be handled with the bare hands without burning the skin.

Write for Complete Details

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Continental Copper & Steel Industries, Inc.
BUFFALO 17, NEW YORK

STRATEGIC MINERALS

(Continued from p. 216)

but also Great Britain, the U.S.S.R., and the rest of the United Nations.

The chain of command to the mining industry was difficult to define precisely because of the overlapping spheres of such agencies as W.P.B., O.P.A., W.M.C., S.S.S., U.S.G.S., and the various state mining bureaus and geological surveys.

Any future mobilization plan must make adequate provision for proper personnel and supplies for the domestic mineral industry and for stockpiling those materials that are unobtainable from domestic sources. These are numerous and important. For example, the United States imported more than 90% of its new supply of the following metals and their ores during 1942-1944: chromite, columbium, nickel and the platinum metals. More than three quarters of our requirements in cobalt was imported. The only tin we got from domestic sources was that reclaimed from scrap and secondaries. Between 50 and 75% of our arsenic, manganese, silver and tungsten was imported. Even for the common essentials (copper, lead, mercury and zinc), from 25 to 50% was imported during the war.

REACTION OF STEEL WITH LADLE BRICK*

IT IS generally recognized that nonmetallic inclusions in steel come from two principal sources. First are the chemical reactions in the furnace, or in subsequent deoxidation, resulting in slag which does not free itself from the metal. Much information has been published concerning these chemical reactions and their control through proper attention to slag viscosity, composition of deoxidizers, and other qualities. The second source is erosion of ladle refractories, such as lining brick, stoppers, nozzles and runners, causing en-

(Continued on p. 220)

*Extracts from "The Interaction of Liquid Steel With Ladle Refractories", by Carl B. Post and George V. Luerssen, *Journal of Metals*, A.I.M.E. Metals Transactions, Vol. 1, January 1949, p. 15 to 26.

WHY 4 TYPES OF KODAK INDUSTRIAL X-RAY FILM?

Because

Radiography in industry meets widely varying conditions—differences in density of materials, in size of objects, in type of radiation, and in the capacity of the X-ray equipment available.

No one film, or even two could give best radiographic results under all conditions. So Kodak provides industrial X-ray film in four types.

These afford the choice of speeds, contrast, and graininess that assure dependable, uniform results even under difficult situations.

TYPE M . . . provides highest contrast and exceptional detail under direct exposure or with lead foil screens—has extra fine grain, and speed is adequate for radiography of light alloys at average kilovoltage and for much million-volt work.

TYPE A . . . has high contrast with greater speed. For study of light alloys at lower voltage than practical with Type M, and at 1000 KV, for heavier parts than the finer grain film permits. Used direct or with lead foil screens.

TYPE F . . . offers highest available speed and contrast when exposed with calcium tungstate intensifying screens. Film has wide latitude with lead screen exposure either to X-rays or gamma rays.

TYPE K . . . has medium contrast. Chosen where speed is important and calcium tungstate intensifying screens are not used. Especially advantageous in studying heavy steel parts by gamma rays, and for the fastest X-ray diffraction exposures.

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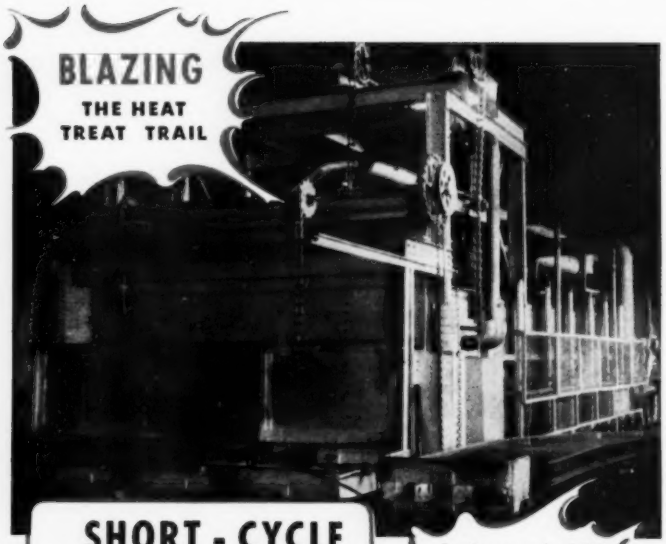

SHORT-CYCLE MALLEABLE ANNEALING FURNACE

Another example of Holcroft "trail blazing"—the first radiant tube continuous furnace for short-cycle malleable annealing, installed more than 10 years ago and still producing economically.

DEVELOPED BY Holcroft IN 1936

Short-cycle malleable annealing is a fast, economical process which offers the following advantages to large-volume manufacture:

- The process requires as little as *14 hours*, as compared to *several days* for other methods. This means reduced inventories and faster shipments.
- It produces *clean, scale-free work* which can go directly to shop or assembly without further processing.
- It permits the use of *light-walled containers* — reduces dead weight by as much as 400%, and cuts fuel bills correspondingly.
- It enables large and small castings to be handled simultaneously.
- Compared to other methods, it gives several times the production per unit of floor area.

Although continuous furnaces are most frequently used, this process is also successfully applied to batch-type furnaces. As with all Holcroft furnaces, each installation is *designed individually* for the specific application, thus meeting every requirement of production and quality with maximum over-all economy.

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REACTION OF STEEL WITH LADLE BRICK

(Continued from p. 218)

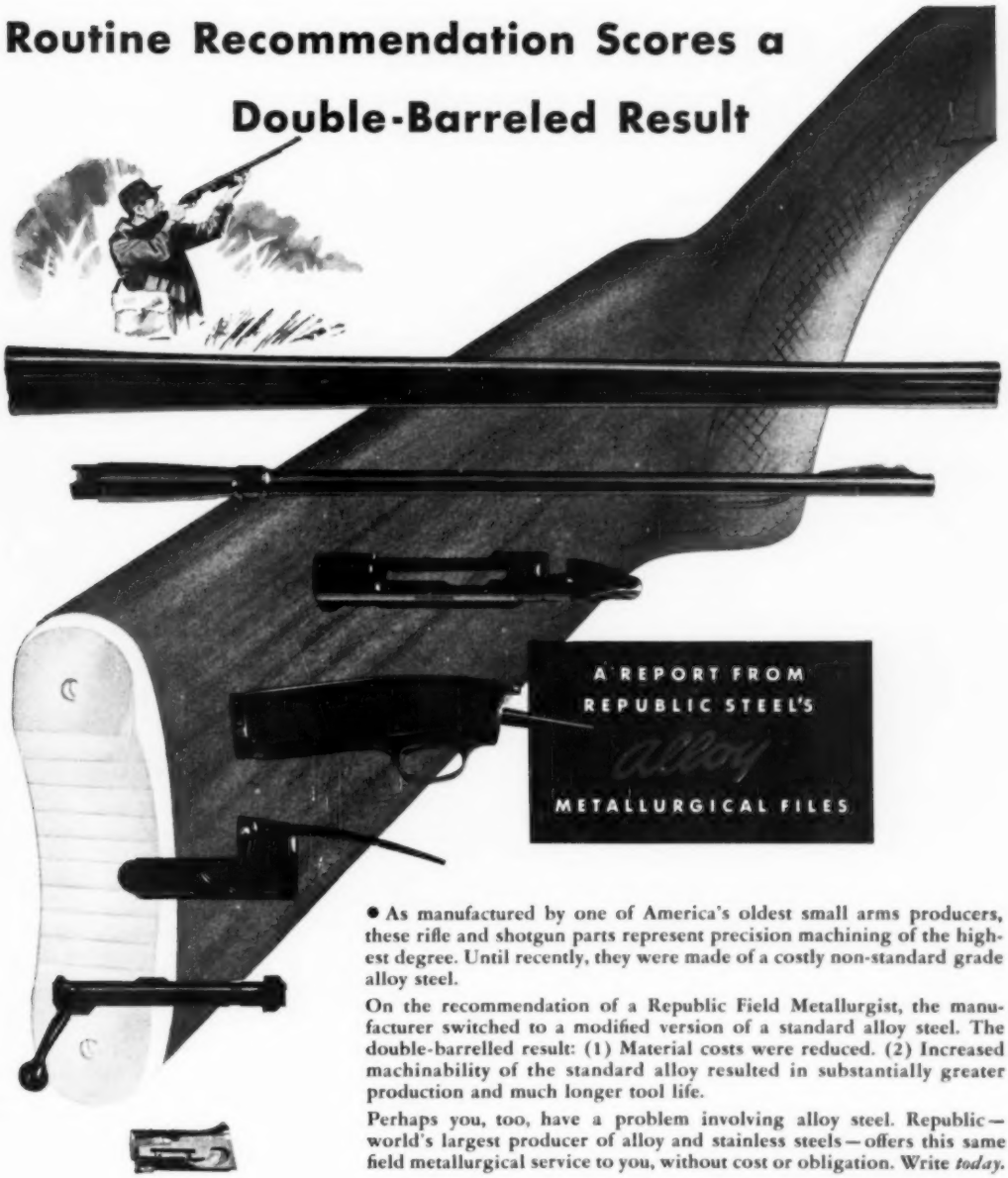
trapped particles or globules of fluxed silicate material. In contrast with the large amount of information available on the first source, relatively little has been published on the subject of erosion, which, in the manufacture of basic electric-melted steel, is the principal source of nonmetallics. This is probably a result of the fact that the problem was assumed to be one of simple mechanical erosion, which could be solved primarily by modification of ladle practices. Good improvements have been made by elimination of slurries in the ladle, better ladle and runner refractories, and more attention to pouring temperatures. It is doubtful, however, that this problem has been recognized in its true light, because it is not a problem of simple mechanical erosion but rather one of chemical reaction between the metal and the refractories. In this sense the problem is as much a matter of physical chemistry as the slag-metal reactions involved in the actual steelmaking process.

The authors have presented data to show the effect of the manganese and silicon contents of basic electric arc-melted steel on the resulting cleanness, as measured by magnetic particle inspection (magnaflux) or step-down rating for heats representative of S.A.E. 6150, A.M.S. 6260 and a 1% C, high-manganese, high-silicon roller bearing grade of steel. These data show that a high manganese content together with a low silicon content in the steel leads to more nonmetallic indications on step-down tests than are present when the manganese and silicon contents are substantially equal. This effect is quite clear on the three grades discussed here, and the effect was apparent when heats were made in succession by fairly rigid control procedures governing the deoxidation practice, refining slag practice, tapping temperatures and pouring times, and using the minimum of aluminum for grain size control. The data apply particularly to basic electric steels melted in 12-ton furnaces and cast into ingots from 10 to 15 in. square and weighing between 1000 and 2000 lb. each.

Experimental data have also

(Continued on p. 222)

Routine Recommendation Scores a Double-Barreled Result



● As manufactured by one of America's oldest small arms producers, these rifle and shotgun parts represent precision machining of the highest degree. Until recently, they were made of a costly non-standard grade alloy steel.

On the recommendation of a Republic Field Metallurgist, the manufacturer switched to a modified version of a standard alloy steel. The double-barrelled result: (1) Material costs were reduced. (2) Increased machinability of the standard alloy resulted in substantially greater production and much longer tool life.

Perhaps you, too, have a problem involving alloy steel. Republic—world's largest producer of alloy and stainless steels—offers this same field metallurgical service to you, without cost or obligation. Write *today*.

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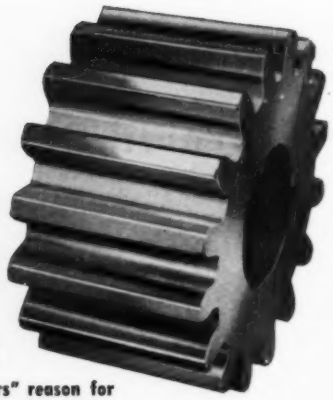
Ampco Bronze Gears



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You can count on Ampco Bronze to stand up under the most brutal punishment. This extra stamina is all-important *in any gear*—from a thimble-size drive for a fishing reel to the rolling-mill gear which is illustrated below.

Whether you are designing a new gear or rebuilding old equipment, play safe by selecting the Ampco alloy and form that fit your needs. Get a gear that stands up under impact and fatigue with unbelievable resistance to wear—that outlasts any gear on the same job. Ask your nearest Ampco Field Engineer for recommendations and assistance.

SAND-CAST AMPCO METAL—Massive 2416 lb. worm gear which plays a critical part in the "screw-down" mechanism of a giant size rolling mill.

CENTRIFUGAL CASTING (including teeth)—Used as a boom hoist gear on large excavating shovel. Withstands wear, fatigue, shock, and abrasion caused by dust, dirt, and loading.

EXTRUDED AMPCO METAL—Tiny drive-gears and level-wind gears for a fishing reel; designed to give perfect performance and service under widely varied conditions.

WELDED ASSEMBLY — An Ampco centrifugally-cast ring welded to a mild steel hub and web with Ampco-Trode 10.

***CONTINUOUS-CAST AMPCOLOY**—Bronze rim with die cast aluminum hub and web. This eccentric gear is proving its value by giving long, satisfactory service in many automatic home washers—and at a savings to the manufacturer.

*Produced by American Smelting and Refining Co. under a patented process.

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REACTION OF STEEL WITH LADLE BRICK

(Continued from p. 220)

been shown which indicate that the manganese and silicon contents of the liquid steel, as expressed by the ratio of manganese to silicon, do in fact affect markedly the silica content of slag buttons collected from the sides of ingots. Qualitative microscopic data indicate that a large percentage of nonmetallics which cause magnaflux and step-down rejections have the same characteristics as these slag buttons and ladle wash.

Detailed calculations are summarized to show that an extension of equilibrium data obtained by Körber and Oelsen in iron melts containing manganese and silicon under SiO_2-FeO-MnO-Al_2O_3 slags accounts reasonably well for the observed slag patch analyses obtained experimentally.

A detailed picture of the chemical influence of liquid steel on the physical characteristics of the metal-brick interface is presented in view of the above experimental data. The authors adopt the outlook that the majority of nonmetallics which are detected by means of macroscopic tests such as the magnaflux test or step-down ratings have their genesis at the interface between liquid steel and ladle brick, and the nozzle. When liquid steel is tapped from a basic electric-arc furnace into a ladle lined with brick containing about 65% SiO_2, 30% Al_2O_3 and 5% Fe_2O_3, the brick is first softened or melted at the metal-brick interface. Chemical reactions then take place between the liquid steel and this interface so that its chemical composition approaches that of an equilibrium acid slag containing SiO_2-MnO-FeO and Al_2O_3. The chemical composition of this slag will have a marked influence on its viscosity and hence its ability to resist erosion. For silica contents near the saturation value for such slags, that is about 50% SiO_2, coupled with low MnO values, the slag will show a somewhat higher viscosity than would result if the silica content were lower than its saturation value. In fact, the data obtained represent a study of the influence of the manganese and silicon contents of liquid steel on the resulting silica content of this metal-brick

(Continued on p. 226)

MELTING 230 LBS. OF ALUMINUM PER HOUR with Electric Heat

● Pereco Model PF-2121 Metal Melting Furnace equipped with GLOBAR heating elements.

Operating 24 hours a day, this ladling furnace delivers 230 pounds of molten aluminum per hour at 1200°F. Maximum demand while producing the melt is 70 KW at 230 volts under open top conditions. When furnace is idling, metal temperature is held at 1400°F and pot is covered. Energy consumption during this idling period, is about 4 kilowatt hours per hour.

GLOBAR silicon carbide non-metallic heating elements receive plenty of credit for the excellent performance being delivered by this furnace. More accurate temperature control is made possible through the use of GLOBAR elements. Long and dependable element service is assured. Additional benefits are realized in an electric furnace design that permits a cleaner, quieter, more compact operation. Working conditions are substantially improved. Installation of elements is simple and fast. For these reasons, furnaces equipped with GLOBAR heating elements are well worth investigating. For a more complete understanding of operating and installation details write Dept. X-29, The Carborundum Company, GLOBAR Division, Niagara Falls, New York.

GLOBAR Heating Elements
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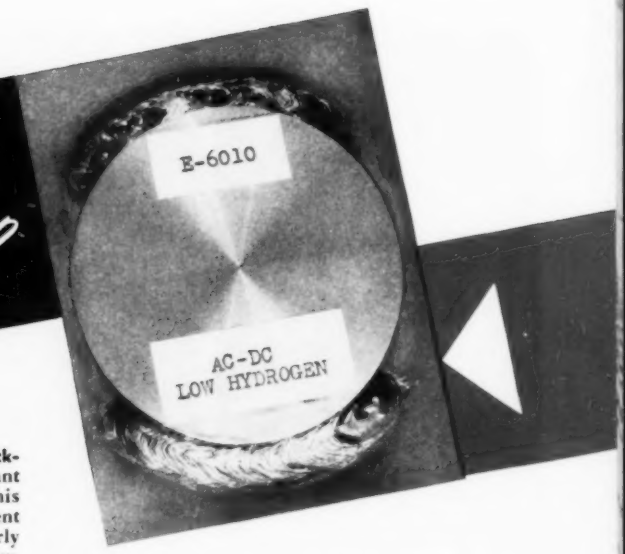
Welding Hardenable or Sulphur-bearing Steels?



1. Fewer structural failures from underbead cracking—Ordinary electrodes deposit a large amount of hydrogen in weldments on hardenable steel. This produces underbead fissures *not* generally apparent in routine inspection, which in turn causes early structural failures in service. General Electric *low-hydrogen* rods have a special coating which materially reduces the amount of hydrogen deposited, thereby largely eliminating the basic cause for such failures.

2. Better mechanical properties—Laboratory comparisons between these low-hydrogen electrodes and class E6010 electrodes show the former to possess higher tensile and yield strength, better elongation, and *higher impact* at both room and sub-zero temperatures.

3. Welds can be successfully enameled without heat treatment—as has been actively demonstrated on both a laboratory and production basis.

4. Materially improved operating characteristics—G-E low-hydrogen electrodes are extremely flexible in application, with either a-c or reverse polarity d-c; spatter is minimized, deposition efficiency is high, penetration is adequate but not excessive. There is little or no tendency for surface holes to occur in metals of relatively high sulphur content—and in all cases the finished weld offers an excellent appearance. (Note lower bead in photo above.)

THESE ARE THE G-E "LOW-HY FAMILY"

W-32 is the "father" of the line, having been offered since 1945. A new, greatly improved version was recently introduced—and this performance-proved electrode is now listed at a new, attractive price.

W-60, W-61, W-62 are three brand new additions, with recommended applications as follows:

W-60—For welding hardenable steels where hazards of underbead cracking are to be eliminated.

W-61—For a wide variety of low-alloy, "high-tensile" steels.

W-62—For use on steel castings and for producing weld deposits having high impact properties at subzero temperatures.

AND THESE OTHER G-E ELECTRODES CAN DO AS MUCH FOR OTHER WELDING JOBS

Mild-Steel and General-Purpose Electrodes—This group of 9 types is headed by W-28, a new general-purpose, all-position rod with an unusually stable arc that produces welds of superior appearance, at high speeds, with minimum convexity. Other electrodes in this group are available specifically for horizontal, vertical, or over-head welding, etc. **Stainless Steel Electrodes**—27 types (16 for d-c, and 11 for a-c or d-c) make this one of the most complete stainless lines available. Each type is keyed to specific AISI code numbers for easy selection. Special, double-carton packaging protects the rod against moisture as well as providing extra protection against transit and storage damage.

Cast-Iron, Hard-Surfacing, & Phosphor-Bronze Electrodes—Herein are some of the more recent additions to the G-E electrode line; W-2075 for making machinable welds on cast-iron; W-94 for abrasion-resistant, hard-surfacing applications; and W-70 for phosphor-bronze welding. They are exemplary of G. E.'s welding laboratories' constant search for better electrodes, improved equipment, and more efficient welding processes.

HERE'S WHY G-E LOW-HYDROGEN ELECTRODES WILL MEAN MONEY IN YOUR POCKET

HERE'S WHAT USERS FIND WITH G-E "LOW-HY" ELECTRODES

Production had virtually stopped at a Pennsylvania machinery manufacturer's plant because cracks were developing in weld-fabricated steel parts. A rush shipment of W-32 from our Philadelphia distributor eliminated the cracking and had them back in production the same afternoon.

Arc welding in general and W-32 electrode in particular played an important part in fabricating this ram or slide for a 200-ton, straight-side crank press. Welded construction with W-32 was used extensively throughout the entire press.

A mid-western transformer manufacturer now swears by W-32 after finding that it completely eliminated a severe cracking and porosity problem in the fabrication of transformer tanks.

You can order these low-hydrogen electrodes from your G-E Arc-welding Distributor today. And ask him for your copy of the new pocket-sized electrode catalog, GES-3571. ***Apparatus Department, General Electric Company, Schenectady 5, N. Y.***

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"A-C or D-C . . . there's G-E Arc-welding Equipment for Every Application!"

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FOR SILVER BRAZING
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Best for brush application and lowest melting solders. It's smooth as cold cream — doesn't lump or harden and removes readily in cold water. You'll find No. 1100 easy and convenient to use on both ferrous and non-ferrous metals.
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REACTION OF STEEL WITH LADLE BRICK

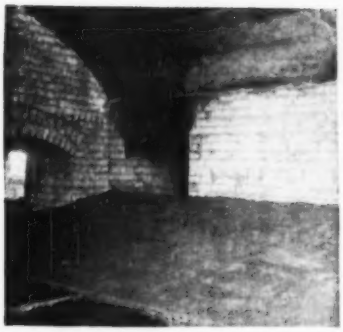
(Continued from p. 222)

interface, as judged from the experimental observations of slag buttons and slag patches from the sides of ingots.

As the steel flows through the nozzle of the ladle the inverse rain of acid slag globules coming from the metal-brick interface in the neighborhood of the nozzle are trapped in the steel and carried down into the ingot mold as the metal is being teemed. These nonmetallics are carried for a considerable distance below the surface of the metal as it rises in the molds, and are swept to the sides and upward as a result of the velocity gradients created in the liquid steel by the force of the stream. The metal is freezing from the sides of the mold inward, and a mushy zone of metal extends for a considerable distance into the body of the liquid steel because of the high rate of heat conduction at the mold wall. Thus these nonmetallics stand a good chance of being trapped in this zone of mushy metal as the ingot is being teemed. Cold metal and slow teeming together or separately will lead to more entrapment of these nonmetallic globules, other conditions remaining constant.

Thus, starting with attention focussed on tapping temperatures, pouring times and several operating variables in the furnace, the electric furnace operator can take a large step in cleaning up nonmetallics in such steels by careful adjustment of the manganese and silicon balance of the steel. The effect is considerable and can be accomplished easily, provided chemical specifications will permit.

In view of the above effect of manganese and silicon on the cleanness of basic electric arc-melted steel, and the importance of such cleanness in aircraft and specialized alloy steel uses, it is suggested that the engineering societies concerned with steel specifications review the silicon contents of those specifications. Such reviews should be directed toward enabling the steelmaker to balance the silicon content against the manganese content where possible, to take advantage of the effect of these two elements on the resulting cleanness of steel.



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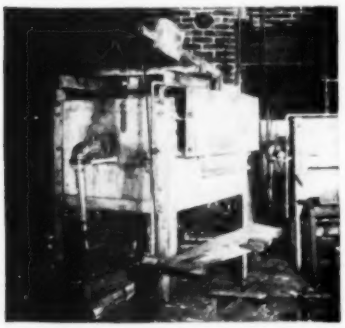

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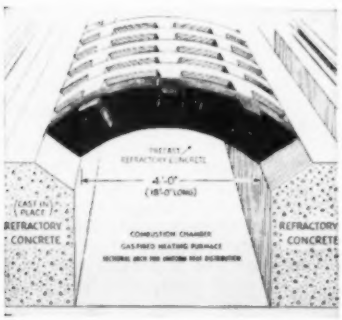

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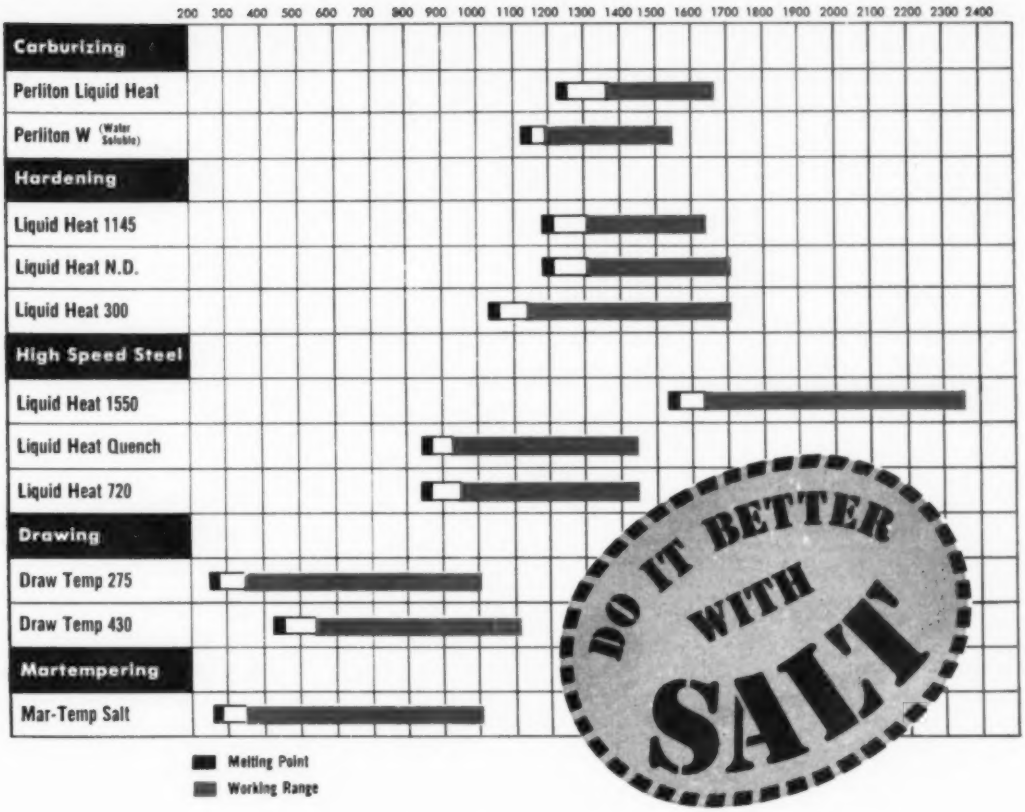
STEELMAKING IN A WELD PUDDLE*

ONCE the matter is brought to your attention you ask, "Why has the slag been ignored in our studies of weld metal?" The answer seems to be that the slag was ignored or was considered inconsequential, because nothing was known about it. Looking back over the history of welding, we find this sort of situation has occurred periodically in the development of all our common welding processes. Slag-metal reactions are fundamental to the production of weld metal, yet there is scarcely any published information concerning them. Slags from covered electrodes are derived from coatings which in the past have been treated as trade secrets. Furthermore, the conditions of arc welding and the compositions of the slags are sufficiently different from steelmaking slags that direct application of steelmaking results to arc welding slags has not been attempted. It is the purpose of this lecture to show some points of similarity and difference.

The mechanism by which steel and slag mix in welding is not understood completely. During globular transfer, either the slag coats each globule, which has about the same diameter as the core rod, or, less probably, the slag transfers independently. In spray transfer there is the same uncertainty. It is certain, however, that slag and steel are well mixed during both types of transfer for about 1 to 5 sec.

To study slag-metal reactions with covered, extruded electrodes, slag was collected from beads deposited in the form of a 3 x 2½ x 1-in. pad. After each bead of the final layers was completed, the slag was removed with a hammer and was collected for analysis for iron, manganese and sulphur or phosphorus, and in some instances silica. (An example was worked out showing how these data — together with a knowledge of the constituents in the coating and electrode and the amounts of both that were consumed — enabled the researchers to calculate the complete composition of the slag, its weight, and the weight of the metal deposited.) *(To p. 230)*

*Abstracted from "The Metallurgy of Covered Electrode Weld Metal", by G. E. Claussen. Adams Lecture, presented before the American Welding Society, Philadelphia, Oct. 24, 1948, *The Welding Journal*, January 1949, p. 12.



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STEELMAKING IN A WELD PUDDLE

(Continued from p. 228)

Slag-metal relationships were studied in four types of covered electrodes containing different amounts of sulphur. The four electrodes correspond with American Welding Society Types 6010, 6012, 7015 and 6020. It is believed that the coatings are fairly representative. In the absence of sulphur (about 1% was added in each, as powdered iron sulphide), these coated electrodes would conform with the intent and requirements of the A.W.S. specification.

The ⅝-in. core rods for all experimental electrodes were from the same heat of rimmed steel containing 0.13% C, 0.43% Mn, 0.012% P, 0.023% S, and a trace of silicon.

When the analytical results were assembled, the sulphur distribution ratio was computed by the same methods used by Grant and Chipman in *Metals Technology* for April 1946. The following molar ratios were taken as necessary for a neutral slag: 2 base : 1 SiO_2; 4 base : 1 P_2O_5; 2 base : 1 Al_2O_3; and 1 base : 1 Fe_2O_3. The following oxides were considered to be bases: CaO, MgO and MnO.

In applying Grant and Chipman's procedure to the welding slags, P_2O_5 was neglected. Ferric oxide was below 1% in all slags and also was neglected. Na_2O and K_2O were treated as bases. It was assumed that TiO_2 was acidic and equivalent to three mols of base. Although it probably exists in slags combined mol for mol with available base, for example CaO:TiO_2, the TiO_2 seems to exert at least as strong an acid effect on the sulphur ratio as silica.

In experiments with electrode Type 7015, which produced a nearly neutral slag (about 0.4 mols excess acid per 100 g. of slag) the sulphur distribution ratio ranged between 1.2 and 2.6—much higher than the equilibrium slags studied by Grant and Chipman. The latter had a distribution ratio of about 0.7. On the other hand, the other three electrodes, producing slags with 1.25 to 2.5 excess acid mols per 100 g., gave slightly higher ratios than the 0.3 called for by Grant and Chipman.

The higher ratios for the welding slags probably indicate that the system weld metal–slag has not attained equilibrium. The low FeO content of the slags of 7015 also

(Continued on p. 234)

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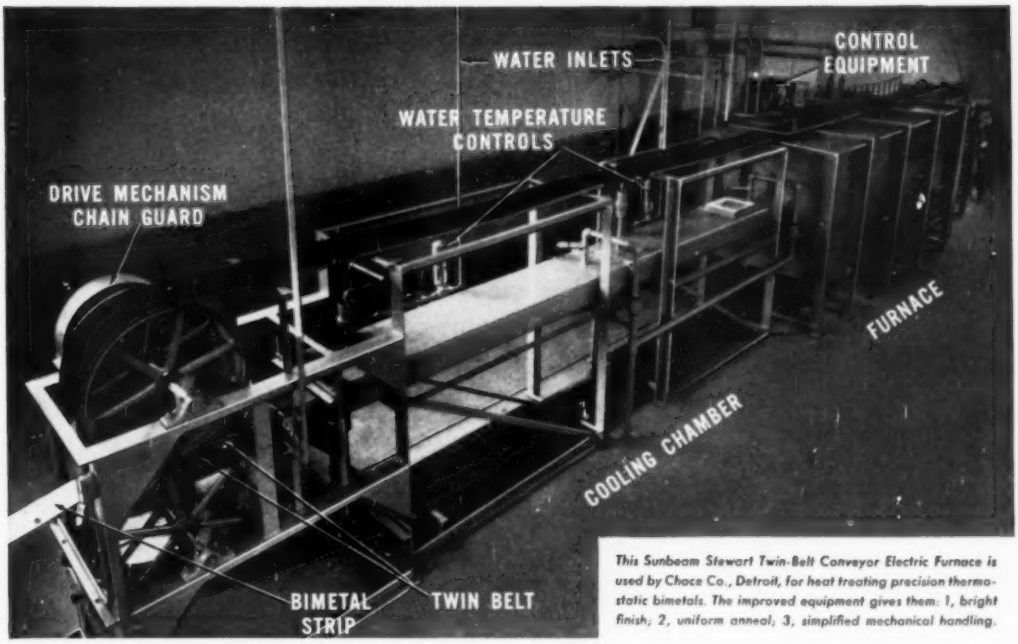

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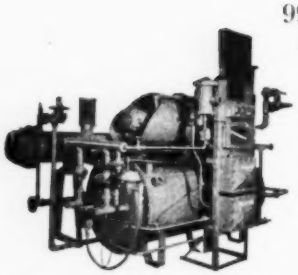

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Bulletin 45 gives full information on low temperature silver solders. Samples sent on request. *American Platinum Works.*

137. Stainless Steel

Greater savings in production costs are possible with Armco's new "ELC" because of its low carbon content. Write for full information on this and many other important facts on production economy. *Armco Steel Corp.*

138. Steel, Cold Finished

New technical booklet on cold finished Jalmet steel just published. Contains complete information on the physical properties of this free-machining open hearth steel, used extensively in production of machined parts. Generously illustrated with photographs and charts. *Jones & Laughlin Steel Corp.*

139. Temperature Measurement

Catalog M1 gives full details on the use of Chromel-Alumel thermocouples and extension leads. *Hoskins Mfg. Co.*

140. Thermocouples

A new 34-page catalog Reference H will furnish complete data on thermocouples, quick coupling connectors, thermocouple wire, lead wire, protection tubes, etc. *Thermo Electric Co.*

141. Tubes, Aluminum

New price and data sheets on seamless aluminum tubes, now available on request. *Revere Copper and Brass, Inc.*

142. Tubing

New 20-page booklet, attractively illustrated in color, is packed with helpful information on tubing. Data includes photomicrographs, properties, specifications, corrosion and fatigue resistance and many typical applications. Also presents fabrication information on cutting, machining, joining, bending, forming and coating. *Bundy Tubing Co.*

143. Turbines

Information on all types of turbo compressors for heat treating, cooling, foundry, and blowing operations. Send for each bulletin by number for particular application. *Spencer Turbine Co.*

144. X-Ray Diffraction

Latest development in X-ray diffraction, the High-Angle Spectrometer, provides higher back reflection angles in greater accuracy and also incorporates the Norelco Geiger Tube-Recorder, giving patterns of relative diffraction intensities on a chart. Write today for complete details. *North American Philips Co., Inc.*

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"Radiography in Modern Industry" a profusely illustrated booklet covering valuable data on radiographic principles, practices and techniques. *Eastman Kodak Co.*

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METAL PROGRESS

7301 Euclid Avenue, Cleveland 3, Ohio

February, 1949

74	91	108	125	142
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90	107	124	141	

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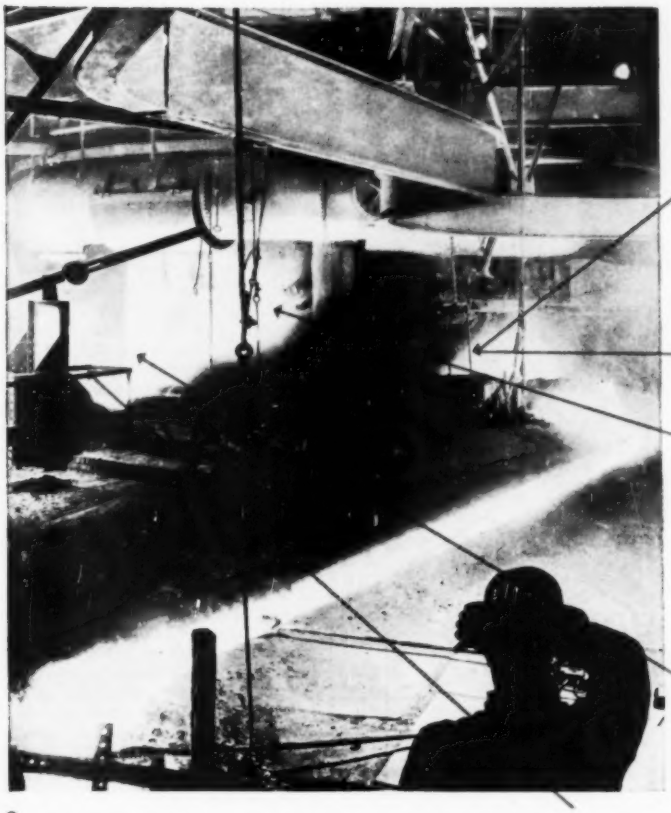
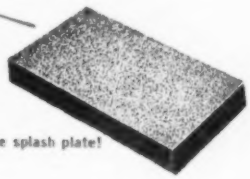


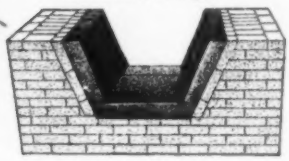
For the cinder notch liner!

For the cinder notch plug!



For the splash plate!

For the runout troughs!



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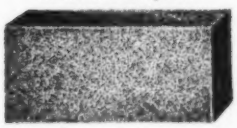

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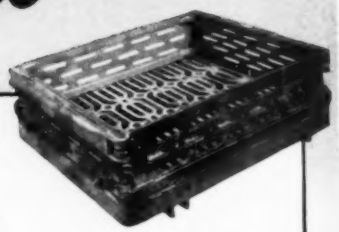

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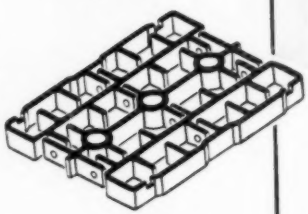

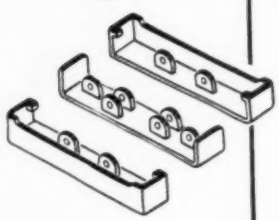

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2-DU-4

STEELMAKING IN A WELD PUDDLE

(Continued from p. 230)

favors high sulphur ratio. Although Grant and Chipman found fluorspar, up to 17%, neutral with respect to sulphur, the high fluorspar content (35%) of 7015 slags may raise the sulphur ratio.

About the same sulphur distribution ratio is obtained if the sulphur is derived from the coating. For example, a ⅛-in. electrode having a 7015 coating but containing no additions of sulphur was deposited as a flat bead on a high-sulphur steel plate 1½ in. thick containing 0.250% S. The welding slag contained 0.19% S, while the bead analyzed 0.12% S. The sulphur distribution ratio was 1.6, which is a little lower than if the sulphur had been derived from the coating.

Instead of iron sulphide, barium sulphate containing 13.7% S was used as a source of sulphur in the coatings of two electrodes. For both electrodes, the sulphur distribution was practically the same as if iron sulphide had been used.

There was considerable porosity in the pad made with unbaked electrodes, but none with baked electrodes. Baking temperature had no effect on sulphur distribution.

A series of electrodes was produced having four different coating thicknesses, including one abnormally thin and another abnormally thick. It was surprising to find that the weld pads contained nearly the same percentage of sulphur. The sulphur ratio increased without corresponding changes in basicity. The smaller the amount of slag, the more rapidly it may attain equilibrium.

The sulphur content of weld metal in practice seldom is as high as the quantities in the experimental series. Nevertheless, fillet welds were made in ½-in. mild steel plates with each group of electrodes. Porosity and cracking were prominent and increased with sulphur content in welds made with electrodes of the 6010, 6012 and 6020 series, producing acidic slags. No porosity was observed in fractures of the 7015 series. Hot cracking was severe in one 7015 experiment giving 0.16% S in the weld metal pad, but was absent in another with 0.054% S in the pad. The insensitivity of the latter to hot cracking probably is related to

(Continued on p. 236)

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STEELMAKING IN A WELD PUDDLE

(Continued from p. 234)

its relatively high manganese content (0.60% Mn in the pad) as well as to low hydrogen.

Similar studies were made of the partition of phosphorus, iron, manganese and silicon. The reader is referred to the original article for details. A brief summary is given of the little that is known about the oxygen content of weld metal — the lecturer adding no new experimental facts. It was also mentioned that water is one of the most important constituents of a coating; its influence on the problems under study awaits future investigation.

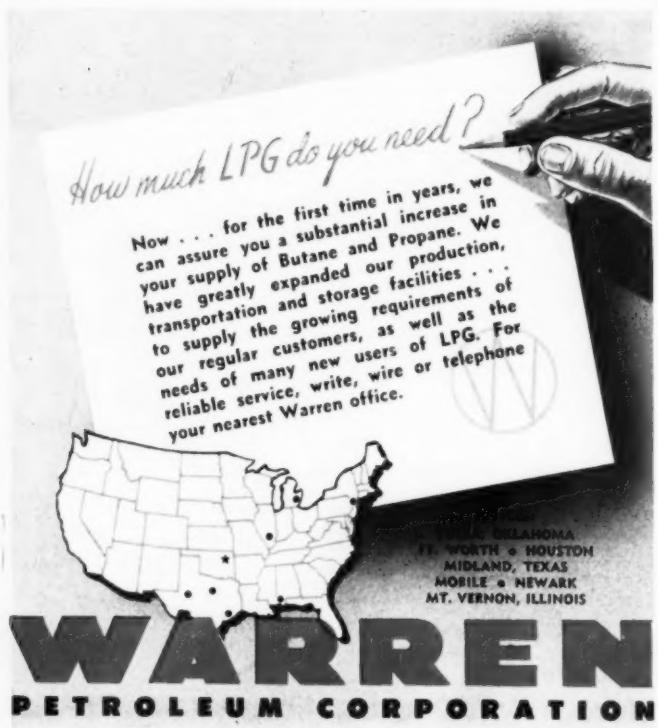
The conclusions of the lecturer, as summarized below, apply only to the particular coatings and welding techniques studied.

1. The sulphur distribution was not far from equilibrium and depended on slag basicity. Not only did the oxides of calcium, magnesium and manganese act as bases, but the oxide of sodium as well. There is good reason to regard TiO_2 as an acid constituent of these electrode coatings.

2. The phosphorus distribution did not reach equilibrium. Phosphorus was transferred to the weld metal to a greater extent than sulphur for a given type of coating.

3. The major slag reactions governing the manganese and silicon contents of the weld metal were between these elements and iron oxide. The reactions appeared to reach substantial equilibrium, which came about through appropriate adjustment of coating weight and coating composition. In 6010, 6012 and 6020 electrodes enough manganese was added to the coating to provide a slag in equilibrium with steel containing 0.25 to 0.45% Mn. Control over hydrogen porosity may be exercised by the relatively high oxygen content of the weld metal. There was sufficient man-

(Continued on p. 238)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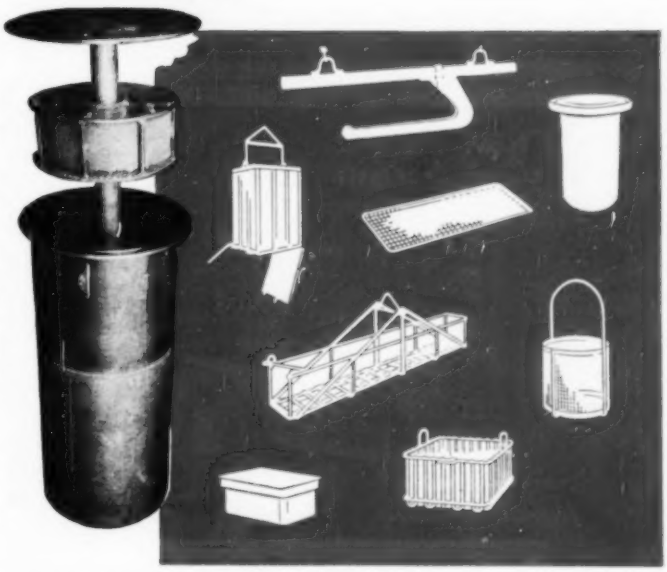

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STEELMAKING IN A WELD PUDDLE

(Continued from p. 236)

ganese in the 6020 electrodes to reduce a portion of the magnetite in the coating to iron. Organic matter in the coating, which carbonized at the tip of the electrode during welding, may have aided the reduction. Of these three series of coatings and slags, all were acid, the 6012 slag being most acid.

4. The lime coating of the 7015 electrodes provided a large amount of semibasic slag with very little iron oxide for reaction with carbon in the weld puddle. The low concentration of hydrogen in coating and arc atmosphere prevented hydrogen porosity in the deoxidized weld puddle during freezing. Enough iron was oxidized to balance the oxidation of manganese and silicon. Beyond its effect on slag fluidity, the large percentage of fluorspar in the coating appeared to play a neutral part.

COPPER IN STEEL*

AS A RESULT of using copper-containing scrap in the steelmaking process, the copper content of steels has been increasing steadily for years. Consequently the role of copper in the steelmaking process and in the finished product begins to attract the metallurgists' attention. Some time ago one of the present authors (Skapski) advanced the idea — based on the results of the analysis of nonmetallic inclusions extracted electrolytically from steels — that sulphur in plain carbon steels is distributed mainly between copper and manganese, the amount of iron sulphide being very small; and that, consequently, the problem of copper and that of sulphur in steel cannot be treated separately.

At the time of the publication of the previous paper (in Poland) little was known about the relative affinities of copper and manganese

(Continued on p. 240)

*Abstracted from "The Influence of Temperature on the Affinity of Sulphur for Copper, Manganese and Iron", by E. M. Cox, M. C. Bachelder, N. H. Nachtrieb and A. S. Skapski, *Journal of Metals*, A.I.M.E. Metals Transactions, Vol. 1, 1949, p. 27 to 31.

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COPPER IN STEEL

(Continued from p. 238)

for sulphur at high temperatures except that at moderate temperatures (below 1000° C.) the affinity of manganese for sulphur is much greater. To gather more experimental data on this subject, the present authors undertook the investigation of the equilibrium constants of the reactions by which MnS, Cu_2S and FeS are formed from the pure elements, over a range of temperatures wide enough to establish the dependence of these equilibrium constants on temperature. From the equilibrium constants, the free energies of formation (affinities) could be calculated. This had to be done rather indirectly by studying the reaction $2\,Mn + 2\,H_2S = 2\,MnS + 2\,H_2$, and subtracting the reaction $2\,MnS = 2\,Mn + S_2$.

The results of the present investigation lead to the following practical conclusions concerning the connection between the amount of copper in the openhearth furnace scrap and the sulphur content of the bath. Because of the relatively high affinity of copper for sulphur at high temperatures, metallic copper present in the scrap may be expected to pick up sulphur from the heating gases by binding it into Cu_2S; thus the sulphur content of the bath would increase with the copper content of the scrap and consequently the desulphurization process would be hampered.

The question remains whether the copper sulphide thus formed is preserved as such in the bath and, furthermore, whether it still exists in the ingot after solidification. Though the authors are inclined — on the basis of other experiments — to believe that a comparatively large percentage of total sulphur exists in finished steel as copper sulphide, they do not think that the present experimental results can be regarded as supporting directly this point of view. Until the equilibrium diagram Cu-Mn-Fe-S and the influence of other components on its shape have been investigated, no further conclusions can be drawn save that the free energy relations of FeS, MnS and Cu_2S in pure systems give a necessary (though not sufficient) support to the possibility of existence of large amounts of copper sulphide in finished steel.

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*The change that improved the honing operation cited above was a mixture of ThredKut 99 recommended by a D. A. Stuart Oil Co. representative. ThredKut 99 is easily mixed or blended whenever a special operation calls for its unusual qualities. Ask for a booklet on D. A. Stuart's ThredKut 99 and other time-tested cutting fluids.

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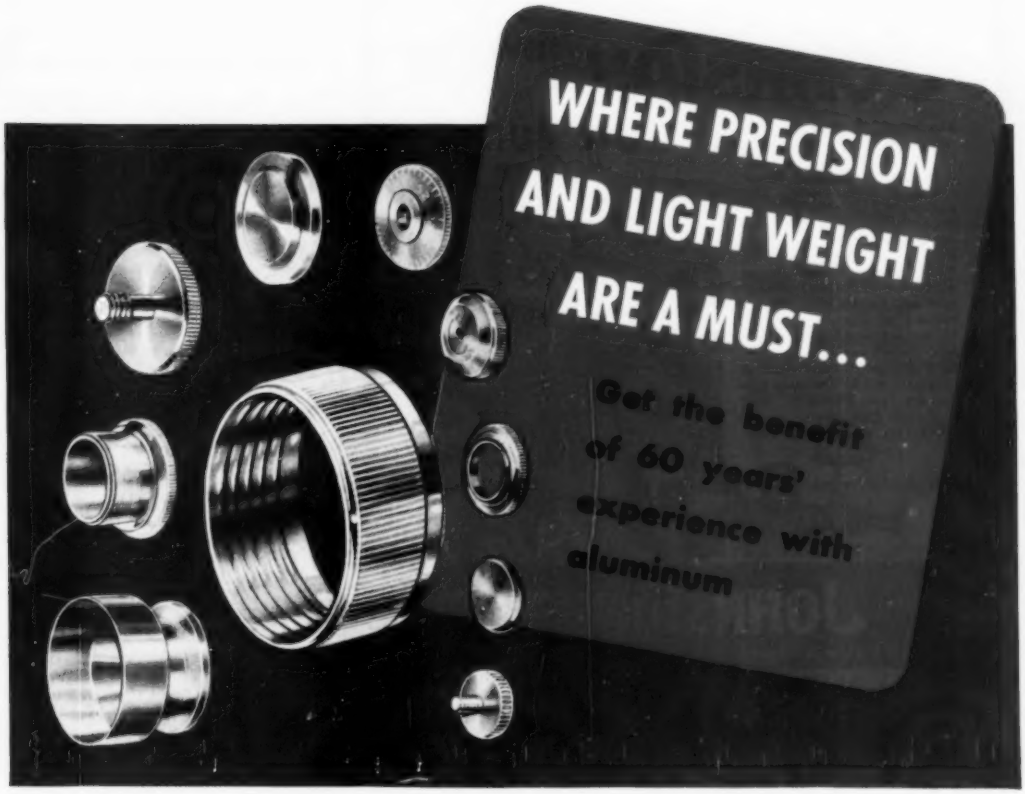

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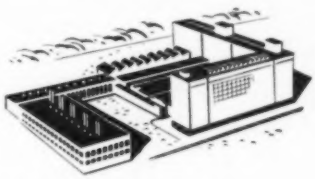

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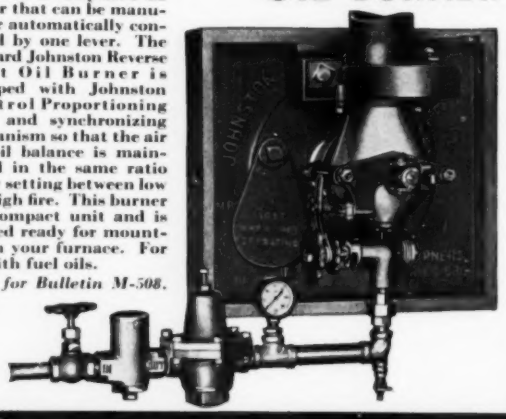

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MEASUREMENT OF INTERNAL STRESSES

LATE in 1947 (Oct. 15 and 16) a series of meetings was held in London on the subject of internal stresses; it was organized by the Institute of Metals, and a number of other British engineering and scientific societies participated: The Faraday Society, Institute of Physics, Institution of Mechanical Engineers, Iron and Steel Institute, Physical Society, and Royal Aeronautical Society. The papers presented have been collected and published, with the accompanying discussion, in a 484-page book (Monograph No. 5) by the Institute of Metals, entitled "Symposium on Internal Stresses in Metals and Alloys", and the Editor of *Metal Progress* has asked for interpretative reviews of the subject matter. What follows is the first, on *measurement*. Later reviews will concern other aspects, such as the origin, control, and effects of internal stress.

A paper by Heyn in 1914 is often cited as the first work on measurement of internal stresses. Heyn's method was to turn successive layers from the outside and measure the remaining bar accurately. It permitted him to compute only longitudinal stresses and called for a number of assumptions, including the value of the modulus of elasticity, and the complete symmetry of stress about the central axis of the specimen investigated. A less obvious but even more damaging assumption was in the degree of precision attainable in measuring the cross-sectional areas of the layers machined off.

Heyn's work was taken over by many investigators, although not much of the work done was ever published. Even now, the information is presented very sketchily — the first part of this latest symposium covers the subject of measuring the internal stresses in 43 pages and its bibliography includes only 114 items, few of which deal strictly with the subject of internal stresses. This is fewer than four contributions per year since 1914 (when Heyn's first paper appeared) from all the industrial countries of the world.

The first paper in the symposium, by Hugh Ford, deals with the mechanical methods of measuring internal stresses; the second, by R. King, describes other physical methods — meaning measurements

(Continued on p. 244)

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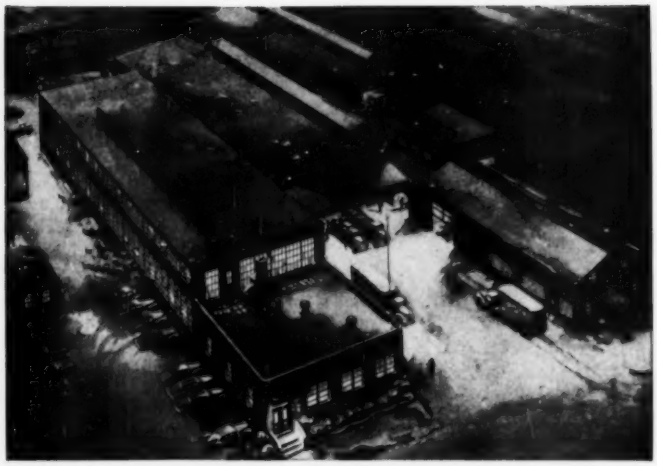

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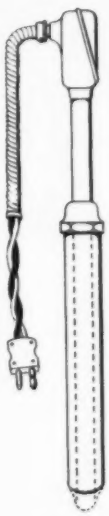

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MEASUREMENT OF INTERNAL STRESSES

(Continued from p. 242)

of magnetism and of electrical conductivity. Three more papers (by D. E. Thomas, W. A. Wood and H. Lipson) describe the X-ray methods. The mechanical methods are *quantitative*, covering the bulk of the specimen examined; they are also destructive. The physical methods have the advantage of being nondestructive and to a great extent easily recorded by automatic devices. X-ray methods are surface and local methods, because the stress conditions can be examined only point by point — one very small area after another.

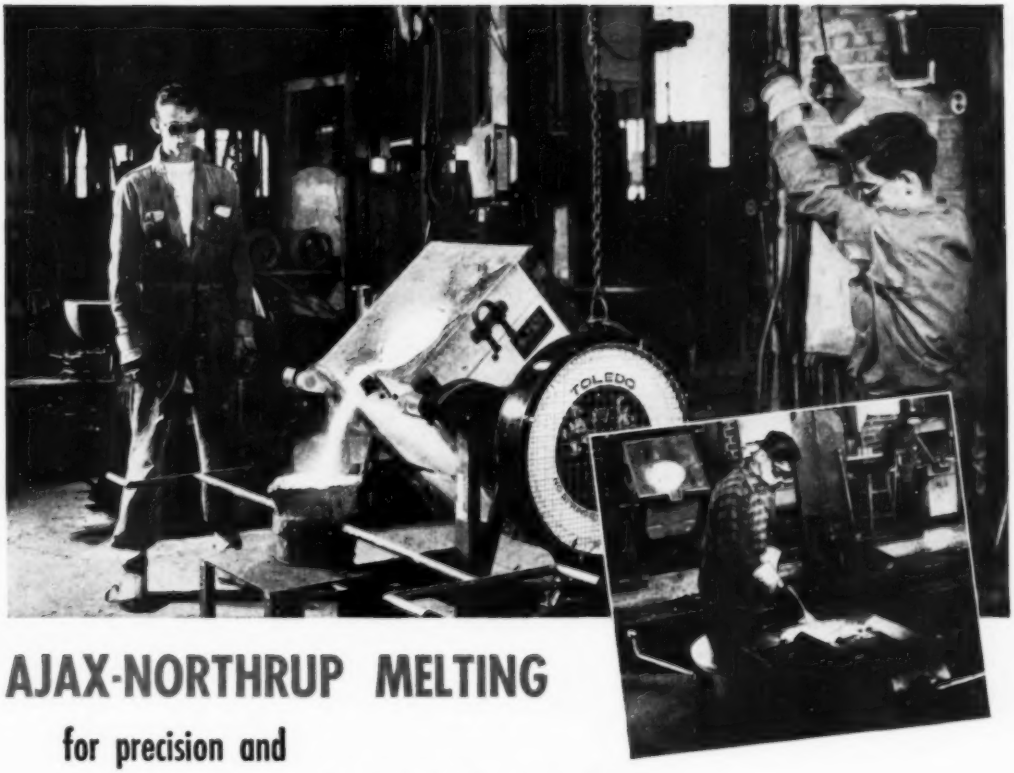
These five papers devoted to methods of measuring internal stresses could hardly be considered as quite satisfying. The only positive knowledge which can be gained from their rapid reading is that the subject is still in a rather primitive and inconclusive state.

For example, the paper by Ford ("Mechanical Methods for the Measurement of Internal Stress") suffers from its extreme brevity. It could tell nothing of interest to the person specializing in such work, and does not begin to give the nonexpert a clear idea regarding the methods used and their mathematical foundations. The bibliography (40 titles) is useful, of course, but it is hard to assume that the metallurgist who merely wishes to be well informed could peruse about 1000 pages in some 20 different British, American and German periodicals. The equations mentioned by Dr. Ford should be treated at a greater length and a critical examination of the theory and practice of each method should be in order.* The use of the resistance strain gages, while generally understood, might also require a more detailed description and examination, illustrated with actual data.*

As it stands this first paper in the symposium is essentially a catalog of goods lined up in no definite

(Continued on p. 246)

*EDITOR'S NOTE: Fortunately, the reader may find a good deal of such information in the recent book "Evaluation of Residual Stresses", by K. Heindlhofer, McGraw-Hill Book Co., 1948. Also, the Institute of Physics has recently published "The Measurement of Stress and Strain in Solids", the proceedings of a conference in Manchester, England, on July 11 to 13, 1946, in which strain gages receive detailed consideration.



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MEASUREMENT OF INTERNAL STRESSES

(Continued from p. 244)

sequence. Not much more could be said about the other physical methods forming the subject of R. King's paper, "The Investigation of Internal Stresses by Physical Methods Other Than X-Ray Methods". Fifty-seven articles are mentioned in his bibliography but only six pages are given to a review of the whole subject! Any person with some knowledge of physics understands that mechanical stresses might change the magnetic and resistivity constants; it requires, however, a substantial amount of experimental illustration to give the garden variety of metallurgist a definite idea regarding the magnitudes involved. Six pages are not enough to obtain a basic knowledge of the subject. For the lack of that basic knowledge, magnetic and resistivity methods are hardly ever used in research; the metallurgist would say that the results are too hard to interpret. On the other hand, instruments based upon these methods are coming into more and more use for industrial control, but the knowledge of their users is limited mainly to knowing which handle or knob has to be turned and when.

The final three papers in this part of the symposium, dealing with the X-ray methods, are of interest mainly for an appraisal of the adequacy or inadequacy of those methods. One need only to examine the back reflection films to notice that the main feature of the "lines" photographed for stressed materials is their diffuseness and general lack of sharp outlines. The total diameter of the rings in the reproductions contained in this volume is less than 40 mm., and it is difficult to see what forms the true "diameter" of a ring when the ring itself has a thickness of 1 to 3 mm. Mr. Thomas states in his paper on "Measurement of Internal Stresses by X-Rays" that, under optimum conditions, a precision of one part in 100,000 is possible, but may decrease to one in 10,000. The photographs shown do not indicate high precision. The ingenious methods used in this work certainly indicate the *degree* of the lattice distortion at a given point under test (about 1 mm. in diameter), but even

(Continued on p. 248)

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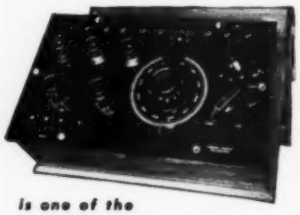

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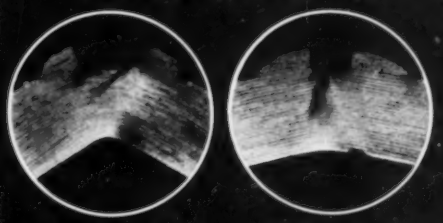
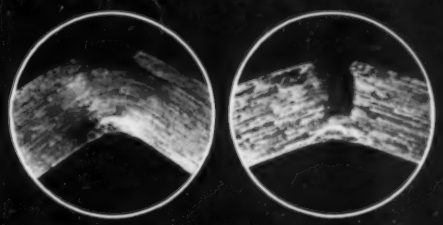


MANGANESE TITANIUM — HIGH STRENGTH PLATE

V-Notch machined prior to bending



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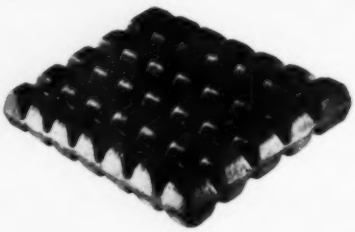

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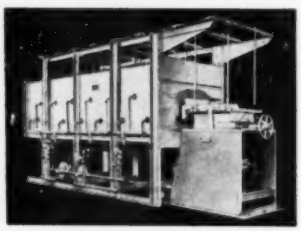

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MEASUREMENT OF INTERNAL STRESSES

(Continued from p. 246)

if the precision of the measurement of the ring's diameter were as high as stated, it would be hard to transform it into a properly computed stress, because neither the modulus of elasticity is known accurately from bulk measurements in tension, nor Poisson's ratio with any degree of precision at all.

The nine pages of H. Lipson's paper ("The Principles of the Interpretation of X-Ray Photographs of Imperfect Crystals") are far more informative but are limited to the study of imperfect crystals. Such crystals are most numerous in all age hardened or quench hardened (and even annealed) alloys. The value of the inverse parameter or reciprocal lattice method is essentially educational, and this reviewer cannot visualize the possibility of highly precise conclusions.

This reviewer would like to add that the whole method of internal stress measurement falls much too short of the requirements of industry. The value of the studies so far is essentially educational, as they tell the practical metallurgist that he must be very careful in his art lest the products of his work get overstressed and cause a lot of trouble. M. G. Corson

AGE HARDENING OF Ag-Cu and Ag-Cu-Al*

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(Continued on p. 250)

*Abstracted from "Note Concerning Some Silver Alloys Having Hardened Structures", by Marcel Ballay and Pierre Vogt, *Revue de Métallurgie*, August 1948, p. 254 to 260.

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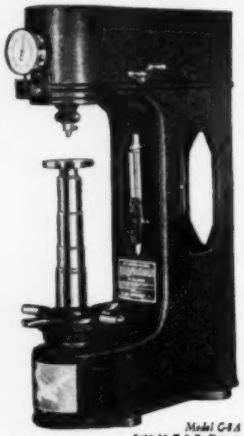

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AGE HARDENING OF Ag-Cu and Ag-Cu-Al

(Continued from p. 248)

F. hardened from 76 to 180 Brinell. The low-copper alloy containing 2.2% Al, quenched from 1290° F. and tempered at 525° F., rose from 67 to 122 Brinell. All tempering experiments lasted 30 min. only, and above the temperatures mentioned softening began rapidly. With more than 2.5% Al the alloys could not be worked commercially. Even at the compositions indicated, the maximum angle of bend around a mandrel was only 90°. Alloys containing no aluminum were more ductile.

Some of the alloys investigated contained either zinc, nickel or tin, but they were no better than the ternary alloys.

No other physical or chemical characteristics of these alloys are given, and no micrographs accompany the paper. No suggestions are made regarding the possible uses of the alloys. In our country, where the commercial alloys must be of sterling content (92.5% Ag), an alloy with 5% Cu and 2.5% Al might prove desirable for tableware. It might be questioned, however, whether such an alloy would retain the brilliant whiteness of sterling silver.

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*Abstracted from "Solid Nuclei in Liquid Metals", by Cyril Stanley Smith, *Journal of Metals*, A.I.M.E. Metals Transactions, Vol. 1, February 1949, p. 204.

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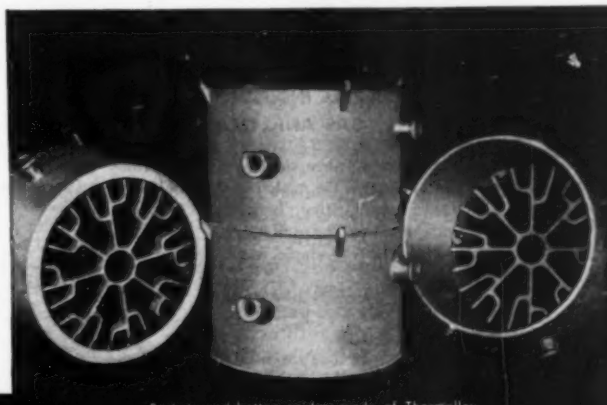

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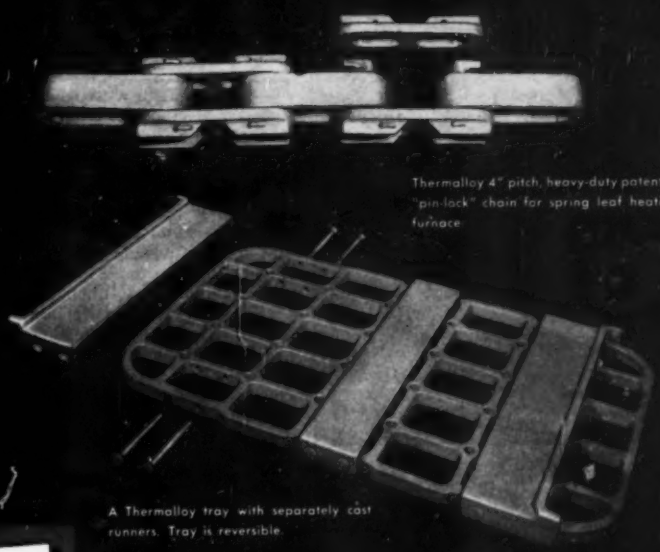

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SPOT WELDING OF TITANIUM

(Continued from p. 200)

Welding Time — The effect of welding time on shear strength is shown in Fig. 2 (right). The pressure was again maintained at 100 lb. and the current was set at the values that produced a high shear strength without "peel-out" of the weld metal in the previous series of welds. The current settings of the machine were kept constant for each sheet thickness. The weld area and the penetration increased considerably with increase in the welding time. At 15 and 20 cycles, the indentation increased to 10 or 15% and the sheets were separated by the accompanying displacement.

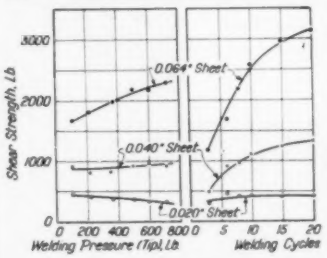
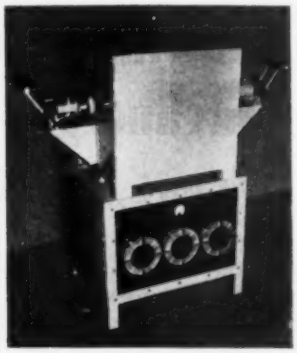


Fig. 2 — Effect of Welding Time and Welding Pressure on the Shear Strength of Titanium Spot Welds

Effect of Pressure — The effect of welding pressure is shown in Fig. 2 (left), for welds made with a duration of 6 cycles and the same current settings used in studying the welding time. Although lower pressures would be more desirable in thin sheet, 100 lb. is about right for the 0.040-in. sheet; if higher pressures had been used for the thick sheet, the welds would have been stronger. In 0.064-in. sheet, the size and structure of the weld changed only slightly with increasing pressure. Penetration varied irregularly between 75 and 85%, and indentation did not exceed 3%.

Discussion — Because all welds were made with one size of tip (¼-in. diameter), these results cannot be compared directly with the known acceptable values of shear strength in other metals. The American Welding Society recommends

(Continued on p. 254)



Harper Tube Furnace Model GT-20 HM-30

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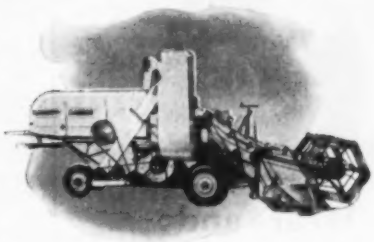
AN IDEA WITH TEETH IN IT!

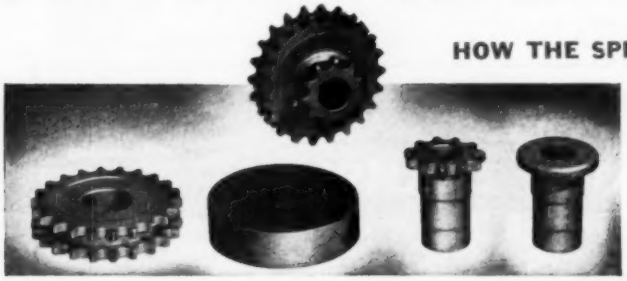
Here's the idea — Instead of casting, forging or machining from the solid, braze sprockets to their hubs with the low temperature silver brazing alloy *EASY-FLO.*

It gives you assemblies *every bit as strong as solid metal* and bites off a big chunk of production time and COSTS.

EASY-FLO Brazed Construction is now used by many manufacturers, among them the Massey-Harris Co., Ltd., of Canada, makers of quality farm equipment. Through their courtesy we present "before—and—after" pictures of a TRIPLE SPROCKET used on one of their self-propelled combines.



HOW THE SPROCKET WAS MADE BEFORE



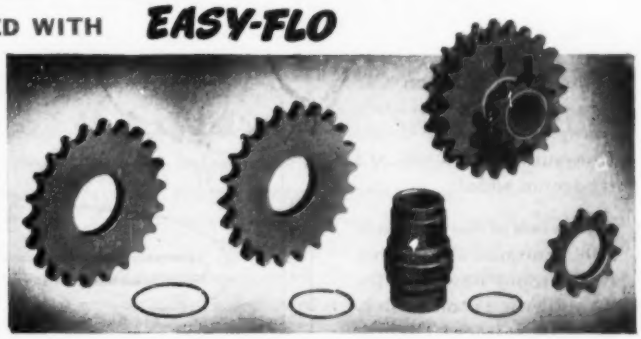
Double sprocket was bored, turned and hobbed from the round stock shown — small sprocket and hub from bar stock slightly larger than outside diameter of teeth. Then the large sprocket was welded by hand to the hub, as you see in the completed piece.

HOW IT IS NOW FABRICATED WITH EASY-FLO

Large and small sprockets are blanked out of ½″ SAE 1045 plate bored and hobbed in groups. Hub is turned from much smaller diameter stock. The 3 rings of 1/16″ EASY-FLO wire do the brazing.

Large sprockets and hub are jigged with a ring of 1/16″ EASY-FLO wire preplaced around hub above each sprocket, then induction-brazed simultaneously in a little over 30 seconds. Vertical set-up aids the exceptionally free-flowing EASY-FLO to penetrate throughout the joint area.

Small sprocket is set up and brazed in the same way with the third EASY-FLO ring preplaced — time 17 seconds. Note in the completed assembly, at large and small sprocket joints (arrows), how the alloy has come all the way through, all around.



THE PAY-OFF — *A much lower over-all cost* for the EASY-FLO fabricated sprocket owing to savings in steel, in machining and in induction brazing over the hand welding time. And a *better product* because the brazed joints with their *full-area penetration* are better than the welded joint with its comparatively large *surface* bead.

BULLETINS 12-A and 15 will give you full facts about EASY-FLO. Write for them today.

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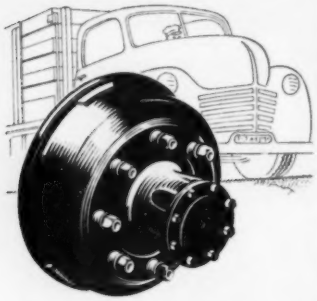

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MP2 F 11

SPOT WELDING OF TITANIUM

(Continued from p. 252)

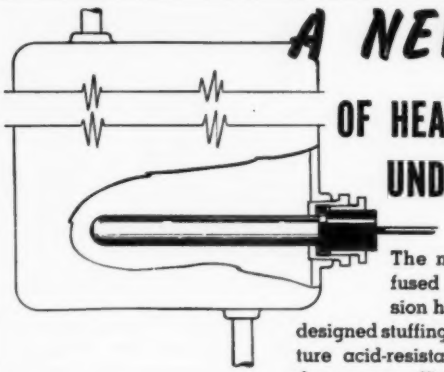
tip sizes of 0.138, 0.178, and 0.224 in., respectively, for the three thicknesses of sheet used here. (In the 0.064-in. sheet, this would provide a tip area almost three times larger than the one used and undoubtedly would produce welds of greater strength. It would also affect the minimum welding current and the penetration.) However, an approximate comparison can be made with the requirements of specifications for spot welding other metals, as shown in Table I. The titanium welds having the highest shear strength without peel-out of the weld nugget were selected for comparison.

The shear strength of titanium welds is considerably greater than the values required for light alloys, and is about the same as for steel of the same tensile strength. Although the penetration of the weld in 0.064-in. titanium sheet exceeds the allowable 80%, this could undoubtedly be remedied by using a larger tip, which would give greater strength as well as lower penetration.

Table I — Shear Strength of Spot Welds in Various Metals

Sheet Thickness, In.	Minimum Shear Strength Required, Lb.*			Titanium, 120,000 Psi. (Observed Values)
	Aluminum Alloys, 56,000 Psi. and Above	Magnesium Alloys	Steel, 70,000 to 150,000 Psi.	
0.020	140	75	440	470
0.040	345	202	1200	1270
0.064	690	357	2440	2640

*U. S. Army Air Force Specification 20011-D



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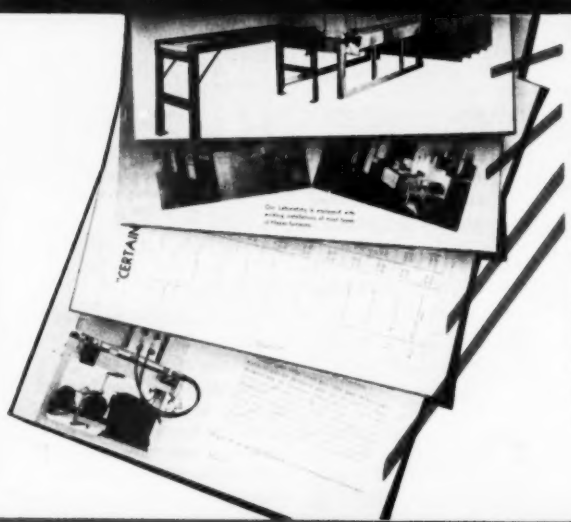

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The company had been operating 12 furnaces constructed with heavy fire brick. One of these furnaces was rebuilt, for test purposes, with insulating materials recommended for the job by Johns-Manville Insulation Engineers. After the furnace was completed, exhaustive operating tests were made and results were compared with the old furnaces.

Test Results

The old furnaces in this foundry performed with an average annealing cycle of 120 hours. The new furnace made it possible to cut the annealing cycle to as low as 72 hours.

Partially completed furnace with J-M materials ready for installation.

The firing time was 80-100 hours depending upon the quality of fuel available. Average firing time in the new furnace was cut to 40 hours.

These results were so striking that the management decided to build 5 additional furnaces of similar construction.

The 6 new furnaces, as engineered by Johns-Manville, are expected to fill all production needs of the plant—replacing entirely the 12 old-style furnaces—resulting in doubled operating efficiency.

Materials Used

The furnace walls were built with thirteen and a half inches of JM-23 Insulating Fire Brick. In every fifth course, vertically, a header row of brick was used with a stretcher course of brick to tie the wall into a solid unit.

To further decrease the heat transfer through the walls, a combination of 2″ thickness of J-M Superex Blocks and 1″ thickness of 85% Magnesia Blocks was used between the insulating brick walls and the outer steel casing.

The arch was constructed with a 9″ thickness of JM-26 Insulating Fire Brick. Over this, 5 inches of Sil-O-Cel Natural Brick was installed in two $2\frac{1}{2}$″ layers. That part of the arch subject to abrasion from the powdered fuel is constructed of fire brick. In order to keep the heat transfer approximately uniform over the entire arch area, that portion constructed of fire brick was backed with a $2\frac{1}{2}$″ thickness of J-M Superex Blocks. And, over this, five inches of Sil-O-Cel Natural Brick was applied.

Cutting J-M Insulating Fire Brick on the job.

J-M 1626 cement was used as bonding agent.

The furnace bottom was insulated first with a 4″ thickness of Sil-O-Cel C-3 concrete. Over this base, ten inches of Sil-O-Cel C-22 brick were laid. A 4″ course of paving brick supplies the wearing surface for the high load-bearing insulating material used for the furnace bottom.

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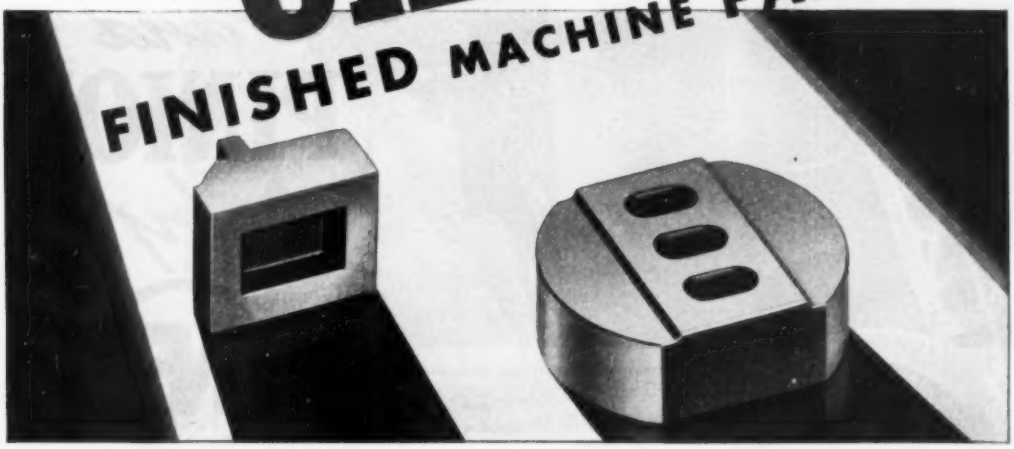

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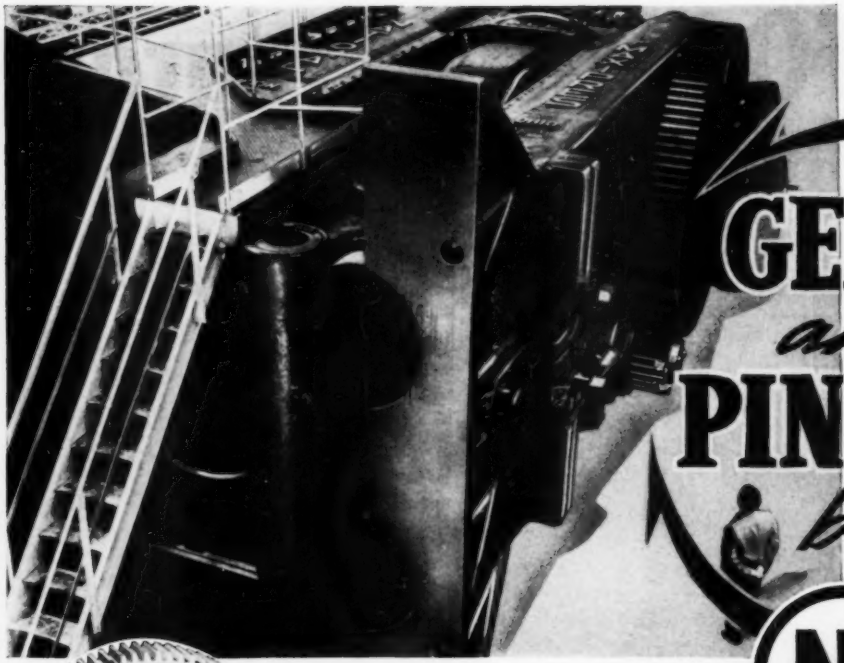

GEAR and PINION by NE

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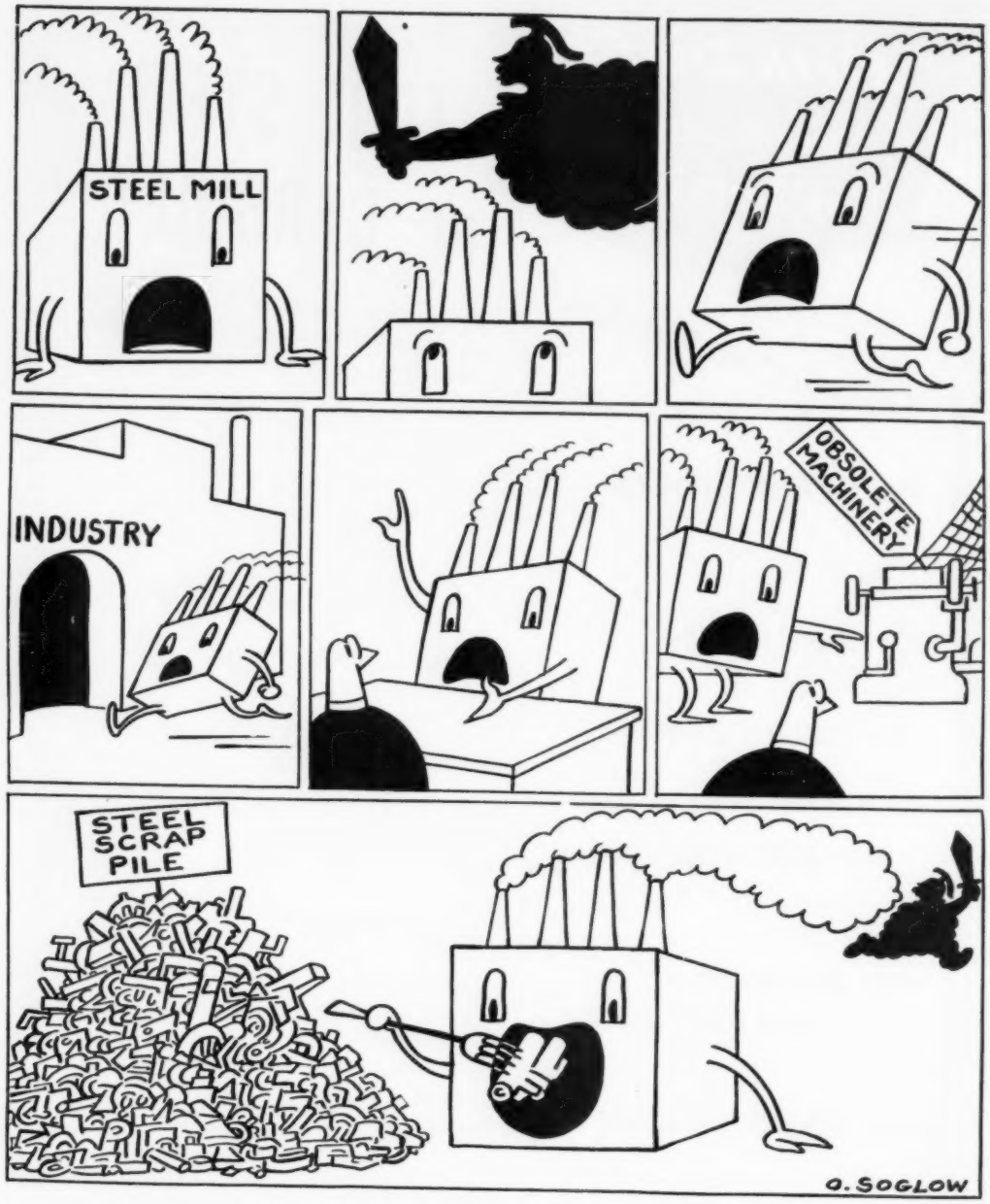

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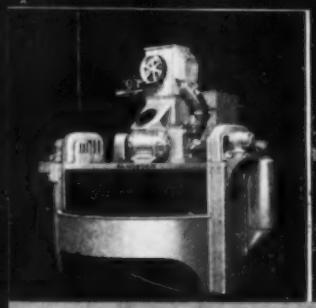

Pangborn Rotoblast Tables for semi-continuous blast cleaning are available in many types and sizes. For cleaning flat castings, the LF Table . . . for castings with deep pockets, odd shapes or vertical surfaces, the LG Table . . . for simultaneous loading and cleaning, the LH "Turn-Style" Table . . . for general-purpose blast cleaning, the Rotoblast "Table-Room."

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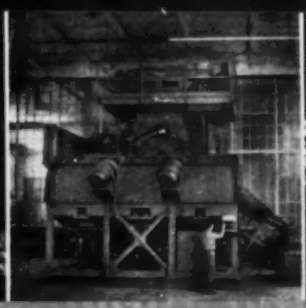

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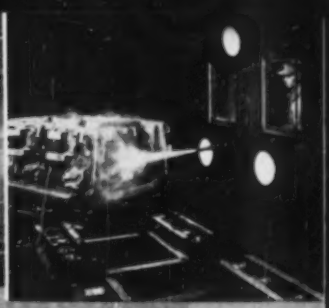

Pangborn Blast Cleaning Rooms. The Hydro-Sand Blast Room simultaneously blast cleans and removes cores, using a high-pressure impelled stream of sand and water manipulated by the operator from outside the room. Pangborn Air Blast Rooms (not illustrated) are custom-built to specifications to clean castings too large for Table or Barrel handling.

which of these Pangborn Blast Cleaning Machines fills your blast cleaning needs?

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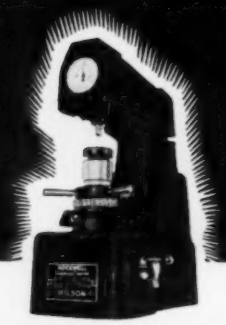

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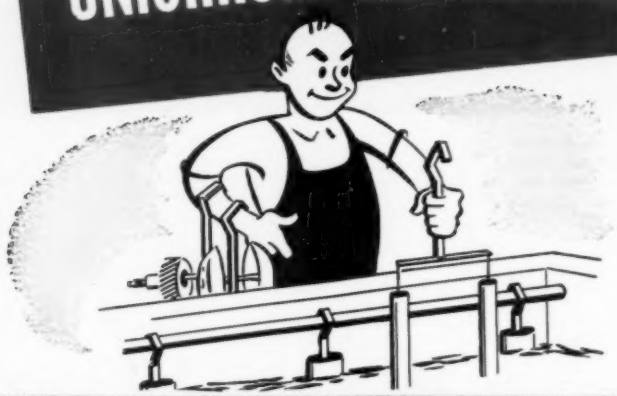

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NO CYANIDE is used in the Unichrome Copper bath—so you not only reduce your stocks of this hazardous chemical, but get a safer bath as well.

CLEAN DEPOSITS never need activation. With no brighteners, no wetting agents used, Unichrome deposits come out clean, ready for the nickel cycle without special treatment.

FEWER ANODES required, because the bath keeps them free of oxides even at high current densities. Why tie up extra money when Unichrome Copper has 100% anode efficiency—with 50% to 75% fewer anodes?

UNICHROME

UNITED CHROMIUM, INCORPORATED

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PROCESSES AND MATERIALS
FOR SURFACES THAT SURVIVE

Chromium Plating • Porous Chromium • Unichrome* Copper
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Unichrome Rack Coatings • Anozinc* Compounds • Unichrome Strip
*Trade Mark Reg. U. S. Pat. Off.

How to pick the correct

STOODY HARD-FACING ALLOY

for every-day wear problems

STOODY HARD-FACING ALLOYS FOR MANUAL APPLICATION

STOODY ALLOY	Hardness	Abrasion Resistance	Impact Resistance	Corrosion Resistance	Heat Resistance	Method of Application	Sizes Diameters	Special Properties	Applications
STOODITE Cr. Mn. Zr. Si. C. Fe.	R-C 54-58	Excellent	Fair	Not Recommended		Bare for Oxy.-Acet. Coated for D.C. Electric	} 1/8, 5/32, 1/4, 5/16, 3/8 x 14"	Polishes readily when subjected to abrasive media. Resists galling and pitting. Good weldability.	Agricultural Tools subjected to earth abrasion. Metal parts subjected to sliding friction: Plow Shares, Steel Mill Guides.
STOODY 6 Co. Cr. W.	R-C 41-43	Good	Excellent	Excellent	Excellent Red Hardness	Bare for Oxy.-Acet. Coated for A.C.-D.C. Elec.	1/8, 5/32, 3/16, 1/4, 5/16, 3/8 x 14" 5/16, 1/4 x 14" Note: 1/8" rods random length	Excellent heat and corrosion resistance. Retains some ductility. Excellent weldability—machinable with carbide tools. Dense deposits.	All equipment subjected to heat, corrosion, impact and abrasion or combinations: Steam Valves, Hot Trimming Dies, Exhaust Valves and Seats.
STOODY 1 Co. Cr. W.	R-C 54	Excellent	Fair	Excellent	Excellent Red Hardness	Bare for Oxy.-Acet. Coated for A.C.-D.C. Elec.	1/8, 5/32, 3/16, 1/4, 5/16, 3/8 x 14" 5/16, 1/4 x 14" Note: 1/8" rods random length	Excellent heat and corrosion resistance. Dense deposits. Excellent weldability. Exceptional hardness and wear resistance.	All equipment subjected to corrosion, heat and severe abrasion: Underreamer Lugs, Woodsaw Teeth, Carbon Scrapers, Wire Guides.
STOODY SELF-HARDENING Cr. Mn. Si. Mo. C. Fe.	R-C 52-56	Good	Good to Excellent	Not Recommended		Bare for Oxy.-Acet. Bare for D.C. Electric Coated for A.C.-D.C Elec. Dual Purpose for Oxy.-Acet. and Electric	1/8, 5/32, 1/4 x 28" 5/16, 1/4 x 14" 1/8, 5/32, 3/16, 1/4 x 14" 5/16, 1/4 x 28"	Bonds well to manganese steel. Forgeable at red heat, high impact strength in relation to hardness; multiple passes. Low cost, fabricated construction.	Heavy equipment subjected to abrasion and impact, particularly parts made from manganese steel.
STOODY SELF-HARDENING 21 Cr. Si. C. Zr.	R-C 53-56	Good to Excellent	Good	Not Recommended		A.C.-D.C. Electric	Bare 3/8" Bare and Coated 1/8, 5/32, 3/16, 1/4" All Bare Lengths 28" All Coated Lengths 14"	Exceptionally high burn-off rate, outstanding in range of application heats, low cost with high wear resistance. Bonds well to manganese steel, cast iron, common steel. Bare rods run as easily as coated on D.C. equipment. Also run on A.C. No slag interference, multiple passes. Down-hand application recommended. Fabricated construction.	All heavy equipment subjected to abrasion with moderate impact. Bulldozer Blades, Dipper Lips and Teeth, Elevator Buckets, all types of Crushers, Grizzlies, Mullers, Impellers, etc.
STOODY 1027 Cr. Mn. Fe.	R-C 45-49	Good	Excellent	Not Recommended		A.C.-D.C. Electric	Coated only 1/8, 5/32, 3/16, 1/4 x 14"	High impact strength. Bonds readily with manganese steel. Deposits are forgeable at red heat. No slag interference. Multiple passes. Low cost rod with alloys in graphitic coating. Excellent welding characteristics in all positions. A.C.-D.C. application.	Recommended for heavy equipment which cannot be positioned: Power Shovel Buckets, Dredge Pump Castings and Impellers, Ore Loading Equipment, etc., Tractor and Shovel Pads, Rollers, etc.
TUBE BORIUM Irregularly shaped Tungsten Carbide particles in mild steel tubes	Moh's 9-10	Extreme	Good	Not Recommended		Bare for Oxy.-Acet. Bare for D.C. Electric	1/8, 5/32, 3/16, 1/4, 5/16 x 14" 1/8, 5/32, 1/4 x 14"*	Extreme abrasion resistance. Composed of graded tungsten carbide particles (Borium) in mild steel tubes. Good weldability by D.C. Electric application. Excellent with Oxy.-Acet.	Provides extreme wear resistance on earth-working, drilling, cutting and scraping equipment. Rough texture also beneficial to prevent slipping on Horse Shoes, Tire Chains, etc.
BOROD Irregularly shaped fine meshed Tungsten Carbide particles in mild steel tubes	Moh's 9-10	Ultimate	Good	Good	Good	Bare for Oxy.-Acet. Coated for D.C. Electric	1/8, 5/16 x 14" 1/8, 5/16 x 14"	Ultimate abrasion resistance. Same composition as Tube Borium but Borium particles much finer mesh. Deposits nearly homogeneous. Good weldability by D.C. Electric application. Excellent with Oxy.-Acetylene.	Provides ultimate wear resistance on earth-working, drilling, cutting and scraping operations, especially on thin metal or small parts: Coal Cutter Bits, Cane Knives, etc.

*See Stoody Alloys booklet for table of mesh sizes

Wear shows up on industrial equipment in many ways. Although abrasion is often present, it is by no means the only wear factor. Heat, corrosion and impact, or combinations of these, are common complications. For any given set of conditions there is one best STOODY ALLOY, resulting in longer equipment life, lower maintenance costs, and reduced down-time. To simplify alloy selection, the various STOODY HARD-FACING ALLOYS for manual application are listed above. For better hard-facing results, refer to this handy chart. More detailed information on each alloy is available from Stoody Dealers or from . . .

STOODY COMPANY 1146 W. SLAUSON AVE., WHITTIER, CALIF.

bend it...
twist it...
stamp it...
spin it...
Use any standard fabricating method you wish!
The bond is inseparable!
SuVeneer Clad Metal's solid copper, monel or nickel cladding is bonded to low-carbon strip steel for keeps! It cannot be separated by mechanical means—you can use full freedom in new product design and count on dependable fabrication results. Get the special benefits of these solid metals combined with a strip steel base—specify and use SuVeneer Clad Metal!
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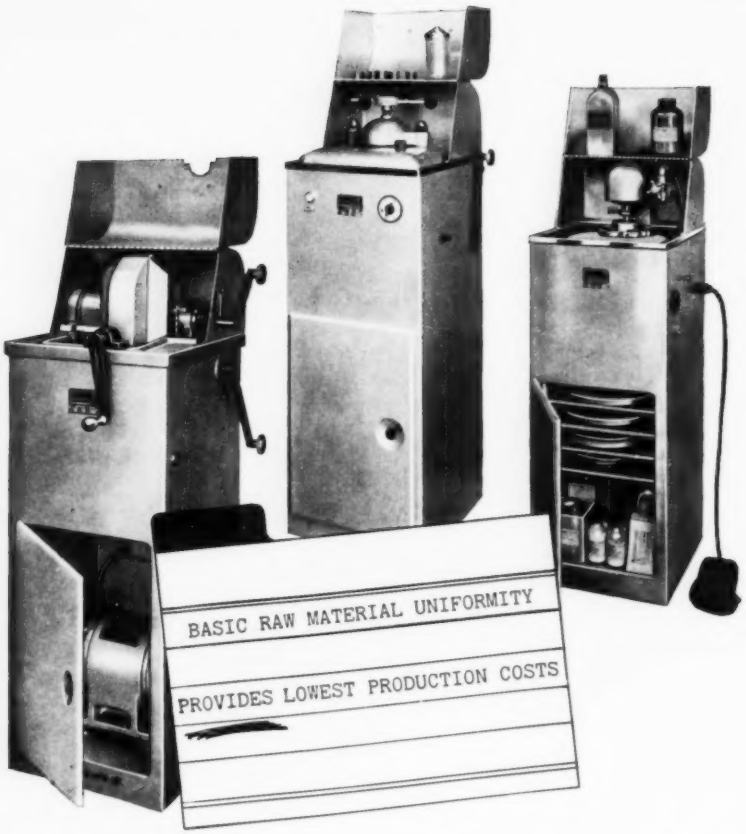

YOUR daily knowledge and assurance that each delivery of basic raw materials is according to specifications, *pre-determines* your production costs. Greatest production, and resultant lowest production cost, is only assured when uniform materials are used. Metallurgical Specimen preparation facilities will provide that assurance. Write today for your copy of our Metallurgical Catalog. It contains thirty-two pages of helpful information and listings of the very latest in equipment for preparing specimens for inspection. Write for your copy today.

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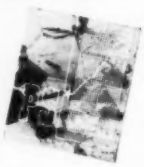

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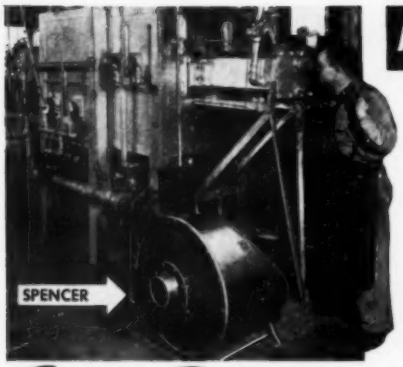
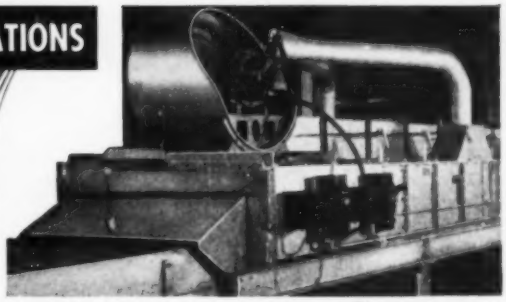
APPLICATIONS

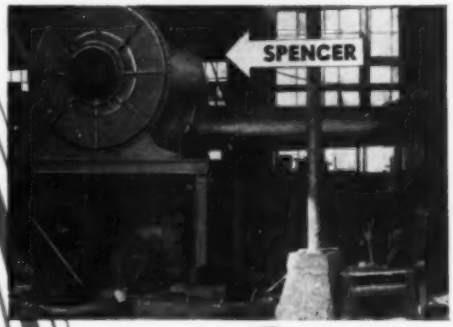


Heat Treating
BULLETIN No. 126

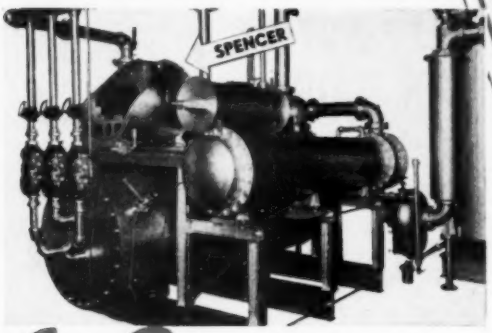


● Ask for the Spencer Turbo Data Book and any of the bulletins mentioned.

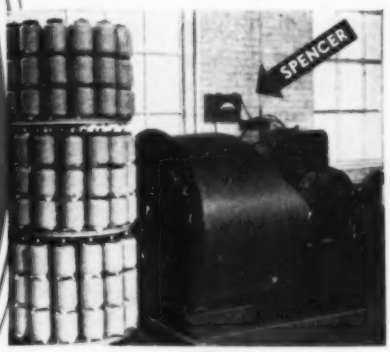
Cooling
BULLETIN No. 127



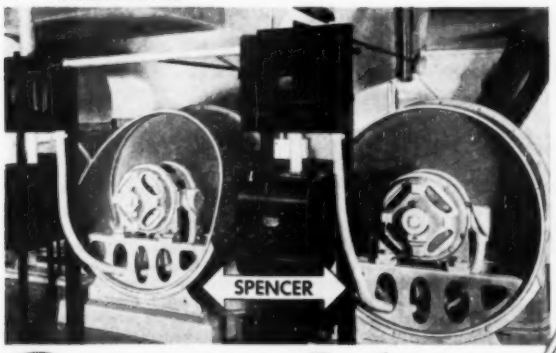
Foundry
BULLETIN No. 112



Gas Booster
BULLETIN No. 109



Blowing
BULLETIN No. 127



Pneumatic Tube
BULLETIN No. 104

THE SPENCER TURBINE COMPANY
HARTFORD 6, CONN.

359-G

SPENCER HARTFORD
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INCREASED DIVERSITY
—*in production control*

To the proven instrumentation for X-ray diffraction, which serves as a practical aid in rapidly identifying, comparing and analyzing raw and finished materials, processes, finishes, etc., NORELCO now adds its latest development in X-ray Diffraction Spectrometry — the High-Angle Spectrometer.

Besides achieving higher back reflection angles than hitherto, with a greater degree of accuracy and higher intensities, the Spectrometer incorporates the NORELCO Geiger Tube-Recorder System which provides patterns of relative diffraction intensities on a chart—offering definite proof of identity for production control in a relatively short time.

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Write *today* for complete details on this important advancement in research and control equipment.

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WE LIKE TO KEEP ACTIVE IN MAINE

"The early settlers of this country used real horse-sense when it came to getting work done. Those who didn't do an honest day's work just didn't eat.

"As I have watched things over the years, I have come to the conclusion that there is no substitute for hard work. Those who get the best things out of life are those who work for them and enjoy the work they are doing.

"Take my work in the shoe factory . . . I have worked here for eighteen years and believe me I have really enjoyed every minute of it. Although I do only a small part of the work turned out on each shoe, I take a great deal of pride in the part I do. We all enjoy our work better because we turn out a good finished product.

"One thing that helps in my work is my home life. I own a little farm that keeps me busy nights, mornings and weekends. I also enjoy hunting, have a good bird dog and whenever I get time during hunting season, we're off to the woods. Yes, Maine is a grand state in which to live, work and play."

Maurice Norton

Maurice Norton is typical of thousands of Maine workers who take pride in their work and really get the most out of life. Excellent manpower is only one of the many advantages you'll find when you locate your plant in Maine. These include: easy access to the nation's largest markets; many raw materials close by; pure processing water; year round production weather; excellent transportation; fair taxes, no State sales tax, no State income tax.

If you are planning to move, expand or decentralize, it will pay you to investigate the industrial advantages of Maine. Write for free booklet, "Industrial Maine".

STATE OF MAINE METAL WORKING INDUSTRY

MAINE DEVELOPMENT COMMISSION, 894 STATE HOUSE, AUGUSTA, MAINE

COLOR has been added to PARK Nitrate Base Salts!

LOW TEMPERATURE DRAWING SALT
M.P.—275° F., 115 lbs. per cu. ft.
Working Range—300° to 1100° F.

HIGH TEMPERATURE DRAWING SALT
M.P.—430° F., 115 lbs. per cu. ft.
Working Range—480° to 1100° F.

PARK THERMO-QUENCH
M.P.—305° F., 115 lbs. per cu. ft.
Working Range—350° to 1100° F.

PARK DRAW BLACK
M.P.—400° F., 115 lbs. per cu. ft.
Working Range—450° to 1100° F.

PARK ALUMINUM SALTS
AL-1: M.P.—430° F., 115 lbs. per cu. ft. Working Range —480° to 1100° F.
AL-2: M.P.—500° F., 115 lbs. per cu. ft. Working Range —550° to 1100° F.

Provides quick visual identification, greater convenience and safety in use!

No chance now of mistaking Park Nitrate Base Salts for other salt compositions. No danger of unmindfully mixing them with Cyanide Base Salts or Neutral Salts. Because COLOR has been added! They're PINK! You can SEE the difference! Makes them more convenient to use. Provides greater safety in their use. And once the salts reach their melting point in the bath, the COLOR disappears completely... without effect on physical characteristics . . . without detracting in any way from Park's traditionally high standard of quality. Time-tested, proved. Acclaimed by major heat treaters the world around. See your Park representative . . . or write today for 36 page technical catalog-manual describing the complete line of Park "Laboratory Controlled" heat treating materials and factory aids.

● Liquid and Solid Carburizers ● Cyanide, Neutral, and High Speed Steel Salts ● Coke ● Lead Pot Carbon ● Charcoal ● No Carb ● Carbon Preventer ● Quenching and Tempering Oils ● Drawing Salts ● Metal Cleaners ● Kold-Grip Polishing Wheel Cement

Park
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8074 Military Ave., Detroit 4, Mich.

In THERMODRAFT

"THE ELEMENT NEVER FORGETS!"

It's Chace Bimetal!

No. 24—Product of the HOTSTREAM HEATER COMPANY Cleveland, Ohio

In the Thermodraft, manufactured by Hotstream Heater Company, Cleveland, Ohio, the use of a Chace Bimetal coil solves a common heating problem through automatic control. Chief cause of trouble on hand fired heating units is the human element. Manually opened drafts are forgotten, causing uncomfortable, unsafe, uneconomical overheating. Thermodraft replaces the human element with an element of thermostatic bimetal—and, "The element never forgets"!

Fixed end (A) of bimetal coil is fastened to control knob (B), the actuating end (C) to damper shaft (D). Control knob is adjusted to desired position between LOW and HIGH, opening damper as indicated by numerals. Since one end is fixed in position by control knob, higher temperature rotates actuating end of coil, turning damper to closed position, reducing combustion. With temperature drop bimetal reacts, reversing rotation of damper shaft to reopen damper. Continuous repetition of this cycle assures automatically controlled heat.

Chace Thermostatic Bimetal as the actuating element for heat responsive devices is available in strips or finished pieces. Consult the W. M. Chace Company engineering department for recommendations.

W. M. CHACE CO.

Manufacturers of Thermostatic Bimetals

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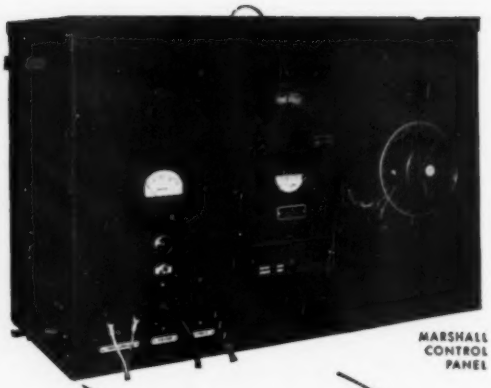
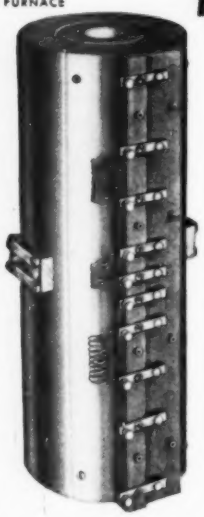


MARSHALL CONTROL PANEL

FOR *Precise* HIGH TEMPERATURE TESTING OF METALS

MARSHALL FURNACE



MARSHALL EQUIPMENT

Leading industrial research laboratories use the Marshall Furnace where accuracy and temperature uniformity are essential. Accurate and uniform tensile, fatigue, creep or stress-strain-rupture tests are readily made with the Marshall Furnace and the Marshall Controller.

Marshall Equipment is readily adapted to many laboratory applications where flexible, accurate and uniform temperature control is required. Marshall Equipment is capable of accurate temperature control within ±1° F.

FOR MORE INFORMATION, SEND FOR ILLUSTRATED TECHNICAL FOLDER

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"No Furnace is Better than its Alloy Parts!"

ARTHUR G. EVANS RETIRES AFTER 46½ YEARS OF SERVICE TO CHASE

Retiring Purchasing Agent of Chase Brass and Copper Company received many tributes of respect and affection at a testimonial dinner. (In the picture he is receiving some tokens including a "Master Bowler Degree".) Arthur Evans, gentleman, sportsman, and discerning Materials Engineer, performed outstanding war service. His friendships with suppliers, based on mutual respect and a keen appreciation of quality in men as well as metals, always gave to him and his fine company, whose spirit and policy he so ably personified, the "priorities" that "regular" people grant to each other without regard to the "priorities" of politics or economics. We are proud to serve Arthur Evans—and Chase—and we wish him the best of everything, always.

"THE MORNING AFTER"—WIFE SPEAKING

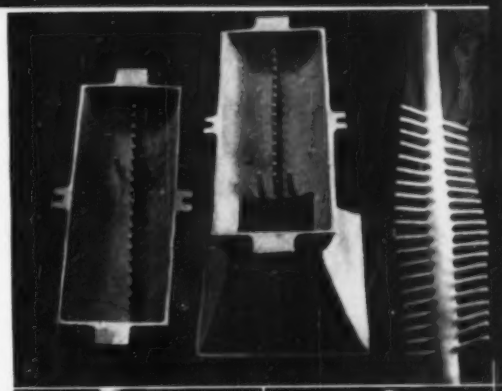
Good morning, my bright international mate,
My outstanding genius in problems of state.
I trust all is clear in that wonderful mind
Which last night remodeled the whole of mankind!
Your handling of Russia, the Ruhr, Palestine,
And China and Greece; it was masterly, fine!
You're sure to be named as "The Man of the Year."
Here's four or five aspirins—swallow them, dear.

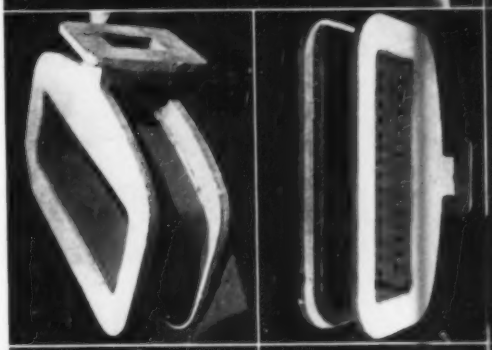
Awake my fine songster! It's well on towards noon.
All morning I've waited, just hoping you'd croon
A measure from "Chloe" or "Deep Rolling Sea"
Which last night you sang until half after three.
You wakened the neighbors, you tripped on the mat
And one of your props was your hostess' hat.
I'm sure she will want you again for tonight—
The life of the party, whenever you're tight.

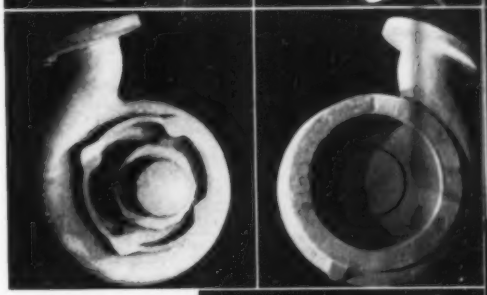
Arise my sweet Prince, but be careful, don't skid,
Arise and consider the things that you did.
The uprooted garden, the splintered garage;
It sounded just like an old-fashioned barrage.
Go see your hostess—and carry a check.
I think if you sign it just "Pain in the Neck"
The bank will O.K. it—it would have to be you—
The clown that went berserk 'twixt dawn and the dew.

So drink up the seltzer, you chattering drone,
It's said to be good for a splintering dome.
I wish I were Sandow; how far would I throw you!
For the next thirty days please pretend I don't know you.
My juvenile jackass, my dim-witted duffer,
You say you feel awful?—Well, goddamit, suffer!

(Contributed by Andy Langhammer, President, Chrysler Amplex Division—Author unknown.)



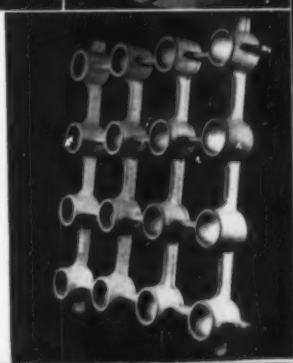




"Strictly the bunk" are claims appearing in recent alloy advertising claiming to "pioneer" the Vertical Centrifugal Casting of stainless steel in metal molds. In 1944, General Alloys was supplying such tube or ring castings for use in the General Electric I-40 jet aircraft engine.

These castings passed 100% X-ray and Zyglo inspection and a 10,000-lb. pressure test as well. In so far as we can discover, this "development" far preceded that of any of the "recent claimants". More later.

Famous Potato Masher on the right. Behold, behold, a set of stainless castings made to same pattern as wooden "spud gnashers" used in the State o' Maine for the past 200 years. Other pictures show a cooled furnace door frame—stainless steel pump castings and a gas carburizing tray. On the heat and corrosion resistant casting jobs where you put service and ultimate life above first cost, General Alloys Company ("oldest and largest exclusive manufacturers of heat and corrosion resistant Alloy Castings") will appreciate your inquiries at Boston or our Branch offices.



THE FOOTSTEPS OF GENERAL ALLOYS MARK THE PATH OF AN INDUSTRY

CHAR

CARBURIZING COMPOUND

. . . gives continuously uniform activity with minimum amounts of new added.

The activated particles are coated with a heavy shell of carbon which adds greatly to the mechanical strength of each particle and prevents the loss of the energizing material. With only 10% to 15% new added, CHAR has a higher and more uniform activity in continued runs than other carburizers with 25% new added.

CHAR PRODUCTS COMPANY

MERCHANTS BANK BLDG. INDIANAPOLIS 9, IND.

KING PORTABLE BRINELL

HARDNESS TESTER

How many times have you carried heavy work to the Brinell Tester? Too often, you'll say.

Here is a 26-lb. portable tester you can easily take to the work and save time and trouble by doing your Brinell work on the job. The King Portable Brinell puts an actual load of 3000kg on a 10mm ball. It can be used in any position.

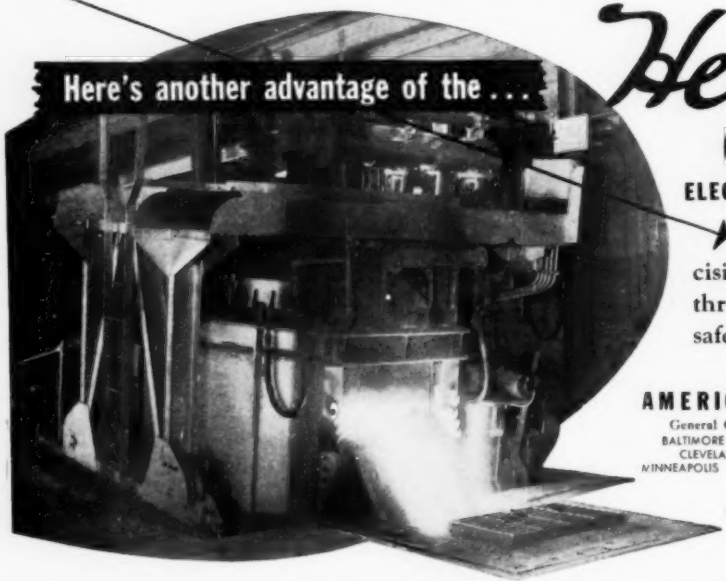
The test head is removable for testing larger pieces beyond the capacity of the standard base.

Throat—4" deep. Gap—10" high. Weight—26 lbs.

Let us show you how we can lighten your Brinell testing.

ANDREW KING

NARBERTH, PENNA.



Heroult

GANTRY-TYPE

ELECTRIC MELTING FURNACE

Mechanisms are precision built, gear driven throughout, for maximum safety and dependability.

AMERICAN BRIDGE COMPANY

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Write for your free copy of the new Heroult Catalog.

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UNITED STATES STEEL

New Light on the structure of metals

Exciting new facts revealed quickly with this budget-wise electron microscope

Immediate Delivery: This low-cost instrument will help you answer many of the "why's" connected with metals . . . give you new data about composition, behavior, and physical properties . . . guide you in perfecting new and better alloys.

Best of all, it's an instrument for small budgets —about one half the price of the world-famous "Universal" Model EMU. Yet it has approximately the same resolving power, and ample magnification (500 X and 5000 X) for 90 per cent of all direct-viewing requirements. Useful photographic enlargements can be made up to 100,000 diameters.

Its simplicity of construction, ease of operation make it ideal for repetitive checking operations and routine analysis.

We'll be glad to help you appraise the possibilities of this console-type microscope in connection with your work. Write Dept. 101-B for new bulletin. R.C.A., Camden, N. J.

Specimens prepared by surface replica technique, metal shadowed to produce three-dimensional effect. Views show only small portion of 8 by 10-inch photographic enlargements. Courtesy R. W. G. Wyckoff, R. C. Williams, and RCA Princeton Laboratories.

RCA

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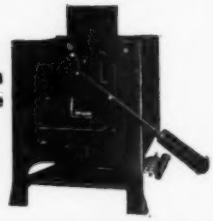

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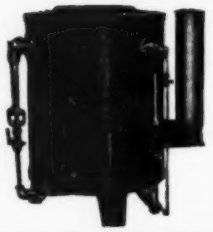

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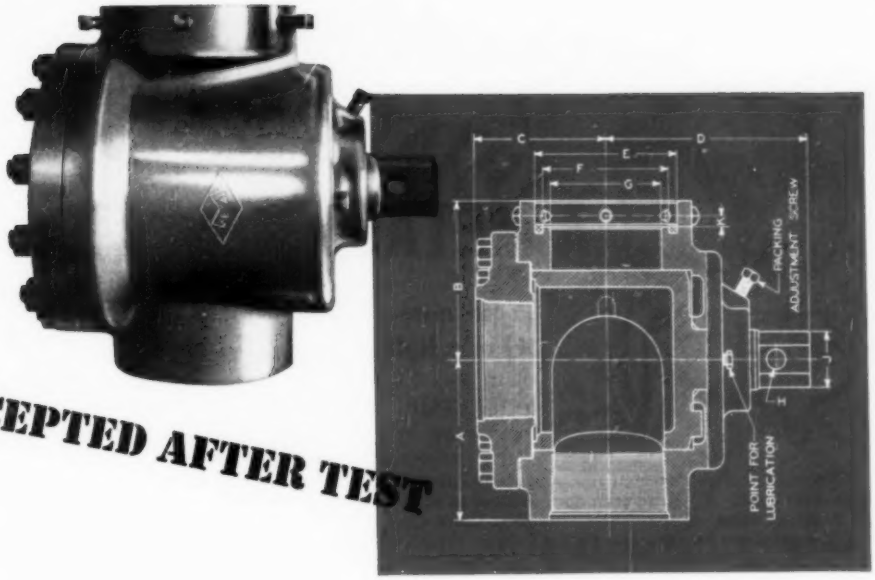

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1. Iron percarbide is:

(a) A new reagent used in the chemical analysis of aluminum and magnesium alloys.

(b) A new tool material developed to retain strength and corrosion resistance at high temperatures.

(c) A phase in the iron-carbon system with the empirical formula $Fe_{20}C_9$.

Answer found on page.....; item No.....

2. Pickling inhibitors in general have the following effect on hydrogen embrittlement:

(a) Increase embrittlement both in mild and in stainless steel.

(b) Inhibit embrittlement of mild steel but not of stainless.

(c) Inhibit embrittlement of stainless but not of mild steel.

Answer found on page.....; item No.....

3. Distinguishing feature of a time-saving combustion technique for steel analysis is:

(a) That an electric furnace heated with metallic resistors is used.

(b) That ten samples can be analyzed at one time.

(c) That a higher test temperature is used.

(d) That accuracy is increased to the third decimal place.

Answer found on page.....; item No.....

4. A combination of tungsten carbide equipment, an induction furnace and silicone die lubricants is used to make the following product:

(a) Bronze wire made from centrifugally cast plate.

(b) Steel die castings.

(c) Hot formed magnesium sheet.

(d) Hot forged high-alloy turbine blades.

Answer found on page.....; item No.....

5. A modification of the wax and plaster process developed at Antioch College for casting aluminum uses the following as basic raw material for the mold, mixed with various other ingredients:

(a) Sand (c) Gypsum

(b) Asbestos (d) Talc

Answer found on page.....; item No.....

6. Aluminum-silicon alloys are notable primarily for:

(a) High strength

(b) Good foundry characteristics

(c) Machinability

(d) Ductility

Answer found on page.....

7. An important advantage of megacycle induction heating is:

(a) That the coil need not conform to the contour of the workpiece.

(b) That it gives deep penetration of heat.

(c) That alloys can be melted in an extremely short period of time.

Answer found on page.....

8. Among the many attractive properties of titanium metal is the following:

(a) Extreme lightness

(b) Electrical properties

(c) Stability in the presence of oxygen and nitrogen

(d) Corrosion resistance

Answer found on page.....

9. A new series of "Techbooks" initiated by the American Society for Metals is designed for the following purpose:

(a) Self-education

(b) College texts

(c) Shop instruction manuals

Answer found on page.....

10. Precision machined parts can be cleaned and held within tolerances as close as 0.0001 in. by a process known as:

(a) Troxide (c) Turbulator

(b) Dip-Agitating (d) Hydro-Finish

Answer found on page.....

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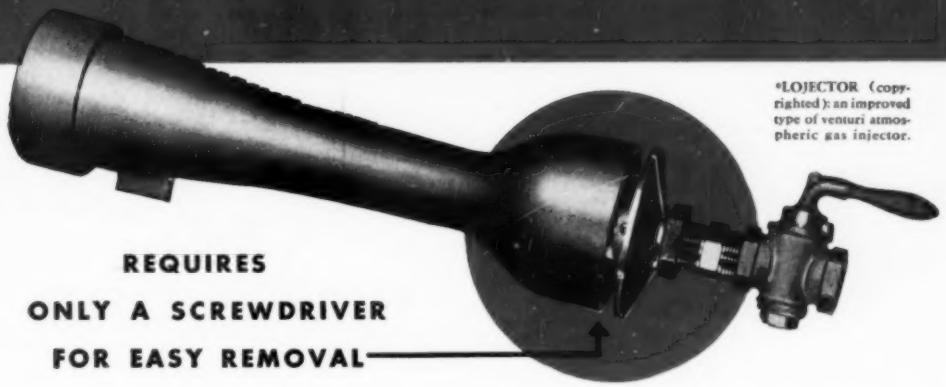

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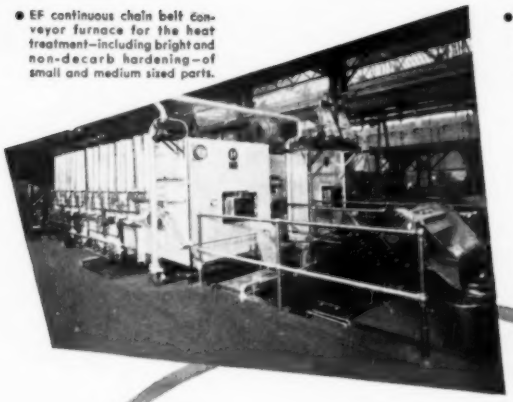

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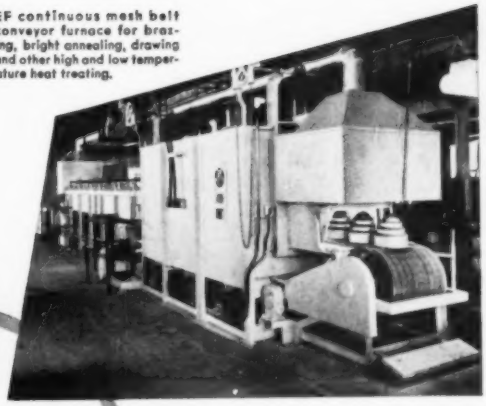

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Flash Pans
Fans
Fire Alarms
Foundry Molding

Glass Tools
Glass Molds
Glass Bottoming Machines
Gasket Coating
Gears
Guns
Geiger Counters
Grids, Vacuum Tube

Heater Elements
Hydraulic Fluids
Hearing Aids
Household Appliances
High-Speed Tools

Ink, Conductive Impregnation
Ingot Mold Washing
Insulators
Internal Comb. Engs.

Joining Compounds

Kiln-car Wheel Bearings
Kilns
Knife Blade Switches

Locks, Automobile
Locomotive Rod Packings
Lead Presses
Line Shafting
Lamp Bases

Machine Tools
Motorcycles
Monotype Machines

Negative Opaquing

Oven Chains
Oxygen Compressors
Oxygen Valves
Ozonator Tubes
Optical Wedges
Outboard Motors

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YES? **"dag"** colloidal graphite dispersions are already helping someone in the same business. They can save you money, too.

NO? **"dag"** colloidal graphite has many useful properties in unique combination . . . it may be just what you need to solve a problem in your business.

"dag" colloidal graphite is: a slippery, dry lubricating solid; resistant to high or low temperature extremes; easily mixed with most liquids and solids; chemically inert; an electrical conductor or resistor, depending on where used; composed of microscopically fine particles; black and opaque; a good conductor of heat; low in photo-electric sensitivity; possessed of a low coefficient of expansion; gas adsorbent; diamagnetic; made up of electrically charged particles; possessed of a specific gravity of 2.00-2.25 and a Moh's hardness rating less than 1.

"dag" colloidal graphite dispersions are most commonly used for GENERAL LUBRICATION, EXTREME (HIGH OR LOW) TEMPERATURE LUBRICATION, PARTING, IMPREGNATION, AND OPAQUING; also for other applications listed on this page.

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I think **"dag"** colloidal graphite can help me in _____
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☐ Send me more information.
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8-10

Meters
Microphone Diaphragms
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Permanent Mold Casting
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Pipe Threads
Precipitators, Cottrell
Plating Machines

Push-pull controls
Printing Presses
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Paper Mill Machinery
Piston Rings
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Quill Bearings

Rubber Tire Molding
Rubber Parts
Roller Gate Chain Pins
Railroad Equipment
Relay Switches
Resistances
Radio Tubes
Razors, Electric
Run-in
Reduction Gears
Rocker Arms

Spray Oil
Steam Engines
Searchlights
Sewing Machines
Screw Threads
Saw Blades
Stator Coils, High Voltage
Selector Switches
Soiling Standards
Stamping Dies
Stone Crusher Machinery
Stopcocks
Swaging Dies

Typewriters
Typesetting Machines
Tapping Tools
Telephone Dial Assemblies
Tractor Engines
Traffic Signals
Trolley Wire Lubricants

Upper Cylinder Lubricants
Ucon Lubricants

Valves
Vacuum Pumps
Variable Condensers

Wire-drawing Dies
Worm Gears